TR-5856-D-1

A COMPARATIVE ASSESSMENT OF THE DEFENSE AND COMMERCIAL SECTORS

31 March 1993

TASC

THE ANALYTIC SCIENCES CORPORATION

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A Comparative Assessment of the Defense and Commercial Sectors

31 March 1993

Mr. Brian Dickson
Mr. Leonard Sullivan

TASC

Key Findings

Key Findings

Industry Cost Distribution

- The defense sector is more vertically integrated than its commercial counterpart
- As a percentage of total industry costs, payroll expenditures tend to increase with participation in the defense market
- Payroll accounts for 30-35% of total industry costs in the defense sector
- In "low tech" ("MECH") industries (regardless of market orientation), production worker wages average about two thirds of total payroll costs
- In "high tech" ("A&E") industries (regardless of market orientation), non-production worker wages are about two thirds of total payroll costs
- Product technology has a stronger impact on industry cost structure than market orientation

Key Findings (Continued...)

Key Findings (Continued...)

Industry Structure and Manufacturing Technology

- Plants in defense-oriented industries tend to employ significantly more workers than their commercial counterparts
- While the defense sector has less machinery and equipment than the commercial sector, its inventory is more modern
- Defense producers lead in the introduction of advanced manufacturing technologies

Workforce Composition

- The defense sector employs a high proportion of engineers and technicians (about 30% in "A&E" industries) and relatively few production workers
- The production workforce in the defense sector is concentrated in high skill occupations (precision crafts, trades, assembly, etc.)
- Volume-oriented workers -- primarily machine operators and automated assemblers -- dominate in the commercial production workforce

Key Findings (Continued...)

Key Findings (Continued...)

Workforce Composition (Continued...)

- Production support workers (e.g. inspectors, guards, and mechanics) account for a relatively large share of the defense blue collar workforce
- Defense-oriented industries employ the same proportion of accountants as their commercial counterparts -- only 1-2% of the total workforce
- Engineers/technicians have much higher administrative manpower support requirements than production workers; BLS data indicate that there are:
  - -- 76 administrative support workers per 100 engineers/technicians
  - -- 22 administrative support workers per 100 production workers
- Large administrative staffs in defense industries appear to be the result of the engineering orientation of defense production
- Defense acquisition regulations may greatly increase engineering requirements in defense-oriented industries
- USD(A) should conduct activity-based case studies on the engineering workforce to assess the impact of DoD acquisition requirements

Key Findings (Continued...)

Key Findings (Continued...)

Civil-Military Integration (CMI) and Defense Conversion

- CMI has the potential to promote the diffusion of new technologies; reduce unit costs/improve quality of defense items; facilitate defense conversion; and preserve emergency defense manufacturing capacity
- The defense sector is most segregated at the upper tiers, where labor skills, manufacturing capabilities, and industry structure are most unique
- Even at the prime contractor level, integration already exists where technological demands are highly similar (e.g., aircraft engines, satellites)
- Defense and commercial production are relatively integrated at the lower tiers, except for the electronics sector
- Conversion may succeed when defense firms/industries adapt existing resources and technologies to expanding, commercial niche markets
- Conversion efforts will be less successful when firms/industries attempt to develop and manufacture products that require fundamental changes in their productive assets for highly competitive markets
- USD(A) should conduct a comprehensive survey to determine the extent, nature, and causes of both integration and segregation

Key Findings (Continued...)

Key Findings (Continued...)

Federal Agency Data Sources

- Federal agency data represent a cost effective -- and under-utilized -- source of information for defense industrial base analysis
- OSD should designate a single office with primary responsibility for coordinating, collecting, and distributing Federal agency data within DoD
- OSD should work closely with other Federal agencies to enhance the usefulness of this data for DoD
- OSD should encourage BLS to make available its industry/occupation database at the 4-digit SIC level
- Federal data should be incorporated into the Defense Industrial Base Information System to be established under the Defense Production Act
- The DEIMS translator should be updated to accurately reflect full contributions of lower tier suppliers

Briefing Organization

This briefing summarizes the results of a study conducted by TASC under the auspices of the Office of the Under Secretary of Defense for Acquisition. The briefing is organized in the following manner:

- The **Introduction** briefly discusses the background and objectives of this study, and outlines TASC's approach;
- The section on the **Characterization of the Defense and Commercial Sectors** employs sectoral data to compare cost distribution; workforce composition and; and costs, industry structure and manufacturing technology in the defense and commercial sectors;
- The section on **Federal Agency Data Sources** outlines a series of measures that would allow DoD to take full advantage of this important source of information for industrial base analysis and planning;
- Annex I provides an overview and several demonstrations of the **Defense Procurement/Industry Cost Translator** (DEPICT), an interactive model that explores the cost structure of the defense industry from several perspectives;
- Annex II describes the primary features of the **Conversion of Industry (COIN) Model,** a stylized interactive tool that explores the impact of technology, production rates, and government regulations on unit costs and workforce requirements through the "conversion" of an appliance factory into a high technology aerospace industry.

Briefing Organization

- **Introduction**

- **Characterization of Defense and Commercial Sectors**
  - -- Cost Distribution
  - -- Workforce Composition And Costs
  - -- Industry Structure And Manufacturing Processes
  - -- Comparative Assessment Findings

- **Federal Agency Data Sources**

- **Annex I: Defense Procurement/Industry Cost Translator (DEPICT)**

- **Annex II: Conversion of Industry (COIN) Model**

Background

The defense industry has entered a period of fundamental transformation brought on by the dramatic decline in the DoD acquisition budgets -- a downward spiral that is likely to continue through the mid-1990s. The fall-off in demand for defense equipment has forced the most sweeping contraction and consolidation of the defense industry since the post-World War II demobilization. Moreover, while units costs for advanced weapon systems continue to escalate, there are growing concerns regarding the ability of the defense industry to incorporate advanced technology into these systems in a reliable and cost-effective manner.

In light of these unfavorable trends in the defense industry, it clearly is in the U.S. national interest to eliminate regulatory or administrative barriers (consistent with reasonable requirements for public accountability, security, equipment reliability and maintainability, etc.) that artificially separate the military and commercial sectors of the national economy. Greater involvement of the commercial sector in the development and production of defense systems would foster improved efficiency and quality in the defense marketplace, and mitigate the impact of the on-going contraction in the defense sector on the nation's ability to adequately reconstitute military production in a national emergency.

Accordingly, DoD is exploring ways to increase the involvement of the commercial sector in defense acquisition -- or, in other words, to promote "civil-military integration." Already, steps have been taken to facilitate and encourage the utilization of commercial items. And many proposals are under consideration that would work to reduce the regulatory and oversight burdens that many argue discourage commercial firms from pursuing opportunities in the defense market.

However, to date there has been no systematic effort to understand the structural differences between the defense industry and the civilian economy, or to determine whether such differences are largely the result of artificial factors like unnecessary regulation or merely reflect the specialized nature of defense production. These issues must be resolved before it is possible to determine where civil-military integration is most likely to succeed, and to anticipate the extent and nature of the benefits resulting from such reform.

The analysis summarized in this briefing therefore represents an initial, top-level effort to fill this knowledge gap, and to establish an analytic foundation for shaping future initiatives that seek to promote greater integration of the nation's productive assets to more effectively meet DoD's needs.

Background

- Dramatic consolidation of defense sector underway
- Unsustainable increases in unit costs, growing quality concerns
- Greater integration of defense and commercial sectors needed to:
  - -- Promote diffusion of advanced technology
  - -- Reduce defense costs and improve quality by taking full advantage of commercial products, manufacturing technologies, and R&D
  - -- Sustain key defense firms by facilitating entry into commercial markets
  - -- Ensure adequate base for reconstitution
- Need systematic approach to identify opportunities for, and constraints upon, civil/military integration and defense conversion

Selected Related Work

In recent years, there has been considerable effort to compare the efficiency of the defense and commercial sectors and to assess the impact of defense acquisition regulations on both system costs and leadtimes, as well as the willingness of commercial-oriented firms to participate in the defense market place. This slide identifies some of the most prominent studies and reports that address some or all of these issues.

In general, these studies conclude that defense regulations and practices unnecessarily increase the cost of items developed and procured through the defense acquisition system, and that these regulations and practices are the primary barriers to greater involvement on the part of many commercial-oriented firms in defense contracting.

Such analyses rely primarily on industry surveys and case studies comparing the costs, leadtimes, etc. of specific military items and "comparable" commercial products. This is a very practical approach that generates vital insights regarding industry perceptions and the impact of specific regulations and administrative practices on individual programs. However, this "micro" approach also has limitations: industry representatives may not be in a position to provide accurate or impartial assessments; commercial and military items studied may not be truly comparable; and case studies may or may not reflect general trends.

This analysis therefore attempts to complement the traditional survey/case study approach with a macro-level comparative assessment of the defense and commercial sector. This approach was in part inspired by ***Overhead Costs and Rates in the U.S. Defense Industrial Base*** (Edward M. Kaitz & Associates, Inc., October 1980), which draws upon Bureau of the Census industry statistics to examine historical trends for key industries within the defense sector. We have attempted to build upon this approach by conducting similar assessments for groups of defense-oriented, mixed output, and commercial-oriented industries, while also incorporating industry data from other sources.

Selected Related Work

- *Adjusting to the Drawdown;* Defense Conversion Commission, December 1992
- *Redesigning Defense: Planning the Transition to the Future of the U.S. Defense Industrial Base*; OTA, July 1991
- *Integrating Commercial and Military Technologies for National Strength*; CSIS, March 1991
- *Use of Commercial Components in Military Equipment;* Defense Science Board, June 1989
- *Practical Functional Performance Requirements: 1985 Summer Study;* Defense Science Board, March 1986
- *Commercial and Military Communication Satellite Acquisition Practices*; RAND, May 1985
- *Overhead Cost and Rates in the U.S. Defense Industrial Base*; Edward M. Kaitz & Associates, Inc., October 1980

Project Objectives

Through our efforts to undertake a systematic, macro-level comparison of the defense- and commercial-oriented sectors, we also set out to explore the feasibility of greater DoD reliance on Federal agency industry statistics for industrial base planning and analysis. This issues will be explored in detail later in this briefing.

Project Objectives

- Utilize Federal agency statistics and other industry-level data (avoid anecdotes, case studies)
- Assess characteristics of defense-oriented, mixed output, and commercial-oriented industry groups
- Determine whether differentials reflect market factors or differences in product technology
- Develop methodology to identify opportunities for/constraints to civil-military integration and defense conversion
- Create interactive tools to analyze impact of acquisition environment and other factors on industry costs

Primary Databases

Here, we identify the primary databases utilized in this analysis. The ***Census of Manufactures*** is a key information source for this analysis. The Bureau of the Census (Census) conducts a comprehensive census every five years which provides industry statistics at the 4-digit and 5-digit Standard Industrial System (SIC) level on employment, payroll, shipments, investment, and value added. In addition, the Census data include:

- The number of establishments and companies in the industry
- The total book value and composition of gross depreciable assets
- Industry expenditures on voluntary and mandatory fringe benefits
- The value and composition of industry investment expenditures
- The value and composition of energy and other material purchases
- Rental payments, contracted services, and other "overhead" expenditures.

During the non-census years, the Bureau of the Census conducts an ***Annual Survey of Manufactures*** (ASM), which generates more timely industry statistics. However, ASM data is limited to the general industry statistics and provides little of the detailed information enumerated above. (Moreover, the ASM is based on a scientific survey of some 56,000 sample establishments; in contrast, the 1987 Census covered 350,000 establishments.) It was therefore decided that, for the purposes of this analysis, it was better to forego the relative "freshness" of the ASM data in order to benefit from the greater detail available in the quintennial Census.

It should also be noted that, in some of the following analysis, we have integrated data from different sources despite the fact that the information may have been collected in different years. While this practice is of course regrettable from a statistical point of view, it is unavoidable given the available data, which are drawn from the 1987-90 period. Since we are looking at broad trends in the defense and commercial markets, which evolve slowly over several years, we are confident that this departure from statistical rigor has introduces no significant bias in the analysis.

Primary Databases

- *Census of Manufactures Industry Series* (Census, 1987)
- *Survey of Shipments to Federal Agencies* (Census, 1987)
- *Industry Occupation Matrix* (BLS, 1990)
- Industry wage surveys (BLS, 1991)
- Input-output table (Commerce, 1987)
- DEIMS translator (DoD, 1990)
- *American Machinist 14th Inventory of Metalworking Equipment* (1989)

Civil-Military Integration

During the project, we contacted a range of firms that produce comparable items for both the defense and commercial market. Our objective was to establish an Industry Advisory Group to review our analysis and facilitate the acquisition of plant-level data. Unfortunately, this initiative did not go forward because of financial and other constraints. Nevertheless, these conversations shed considerable light regarding the extent to which the civil and military sectors of the economy are presently segregated.

Our informal survey suggests that the level of segregation varies considerably throughout the defense sector. For example, prime contractors or system integrators appear to have a general tendency to maintain "sister facilities" -- separate plants or divisions that produce comparable items exclusively for the defense or commercial market. McDonnell Douglas (airframes), Boeing (aircraft and aircraft parts), and Bell Helicopter (helicopters) are prominent examples in this category.

However, even upper tier suppliers appear to operate integrated facilities -- with commercial and military items fabricated and/or assembled on the same production lines -- when technological requirements are very similar. General Electric (aircraft engines), Pratt & Whitney (aircraft engines), Vought ("old" LTV -- aircraft parts), and Hughes (satellites) maintain highly integrated production operations.

At the lower tiers, we found little segregation in firms with a metalworking orientation. For example, Allison Transmission builds transmissions for armored vehicles and heavy construction equipment in the same facility. A Washington representative of a trade association of more than a hundred small firms that produce items for both the defense and commercial market indicated that virtually all of the association's membership combine defense and commercial production in the same facility.

On the other hand, lower tier electronics firms were relatively (but not uniformly) segregated in the areas of microelectronics and electronic systems (e.g., Motorola, Westinghouse, IBM). Sometimes such firms maintain combined fabrication facilities but separated the commercial and military production lines for testing, inspection, and final assembly.

For those firms that have gone to the trouble and additional expense of maintaining segregated facilities, DoD cost accounting requirements and practices, testing and inspection requirements, security practices, and other oversight regimes act as barriers to a more efficient organization of productive resources. (There may also be other contributing factors.) However, other firms have apparently concluded that the benefits of combining facilities outweigh the additional costs and/or nuisance that may be associated with integrating defense and commercial production. More work needs to be undertaken in this area to determine why some firms are capable of maintaining combined facilities, while others are compelled to segregate their defense production.

We recommend that USD(A) undertake a comprehensive survey of defense producers to validate and extend this analysis.

Civil-Military Integration

- Extent of civil-military integration varies with tier position and product type
- The defense sector is most segregated at the upper tiers, where labor skills, manufacturing capabilities, and industry structure are most unique
- However, even at the prime contractor level, integration already exists where technological demands are highly similar (e.g., aircraft engines, satellites)
- Lower tier suppliers generally combine defense and commercial production
- Important exceptions are microelectronics and electronic systems, where final assembly, inspection, and testing are performed in separate facilities
- USD(A) should conduct a comprehensive survey to validate and extend this analysis

Characterization of Defense and Commercial Sectors--Cost Distribution

This section discusses our analysis of the cost structure of the defense and commercial sectors. We will determine whether there are characteristic, structural differences between defense-oriented and commercial-oriented industries. First, we will examine the distribution of industry costs in the defense and commercial sectors.

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- **Introduction**
- **Characterization of Defense and Commercial Sectors**
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Industry Sample

The Census report ***Shipments to Federal Agencies*** provides the basic industry sample for our analysis. This publication indicates the proportion of industry shipments delivered to DoD and other Federal agencies for 63 4-digit SIC industries considered to be important for defense production.[1]

With this data, we divided the industry sample into three market sectors: defense-oriented (at least 75 percent of total shipments provided to Federal agencies), mixed output (26 to 74 percent), and commercial-oriented (25 percent or less). While the Census data distinguishes between shipments to DoD, NASA, DOE, and "other" Federal agencies, we treated all government shipments as "defense-related." We made this assumption because both NASA and DOE procurement have a strong national security orientation, and because the intelligence agencies are folded into the "other" category. Shipments to DoD accounted for about 88 percent of the total; NASA totaled 3 percent; DOE totaled 1 percent; and "other" was 9 percent.

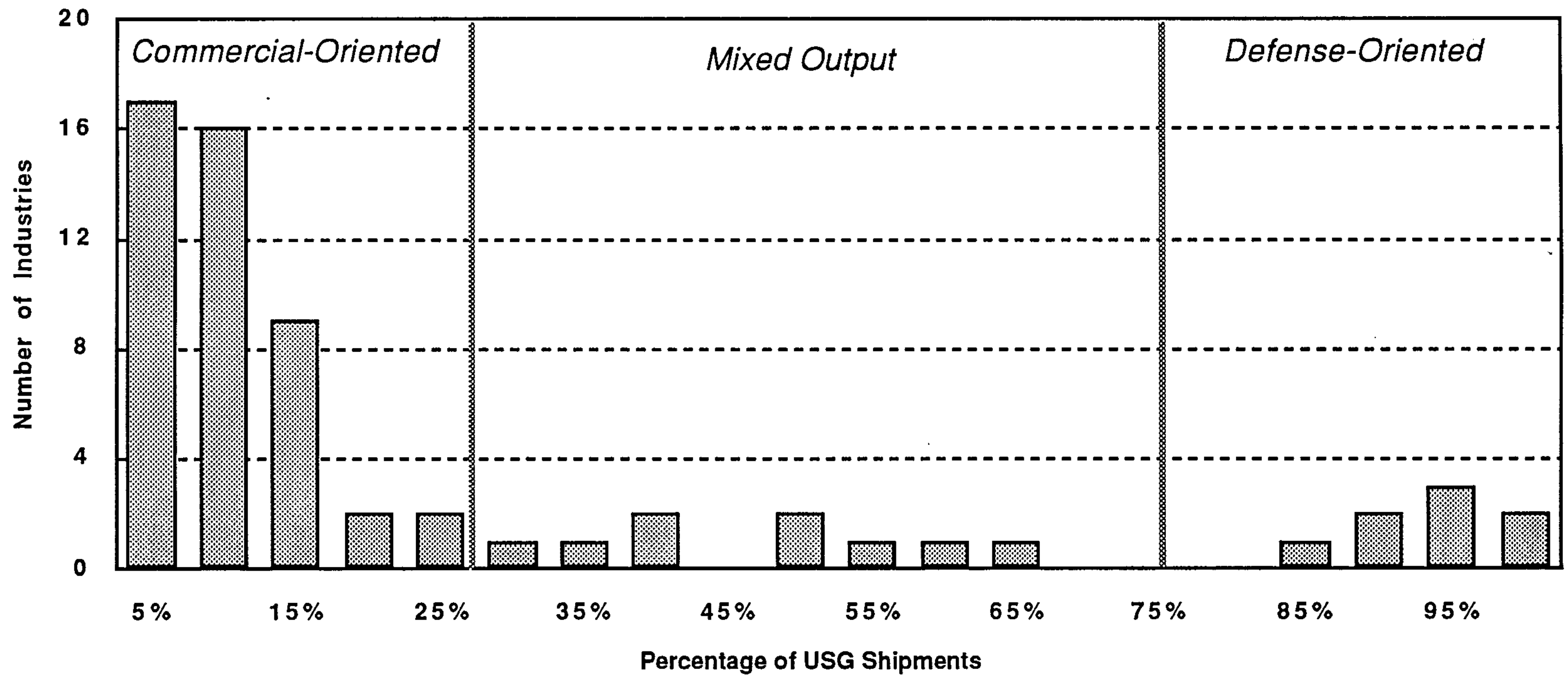
As the slide illustrates, the sample industries fall conveniently into these three sectors. Unfortunately, the Census sample includes few consumer or heavy equipment industries. We therefore added refrigerators and freezers, household audio/video equipment, farm machinery, construction machinery, and railroad equipment to the commercial-oriented sector to ensure a more representative sample.

Aircraft, a key DOD industry, falls into the mixed output sector with 56 percent of total industry shipments provided to Federal agencies. Since the ***Census of Manufactures*** provides limited industry data on the military and civilian components of the aircraft industry, we divided the industry between the defense- and commercial-oriented sectors whenever possible.

[1] Federal shipments are direct purchases by federal agencies as well as all items made to government or military specifications.

Industry Sample

Market Distribution of Industry Sample



Source: Bureau of the Census, 1987.

Market Sectors and Product Categories

In addition to grouping our sample industries into three sectors by market orientation, we also established two broad product categories within each sector: "Aerospace & Electronics" (or high technology) and "Mechanical" (traditional "metalworking") industries.

Since all of our sample industries in the defense-oriented sector are first or second tier industries -- defense accounts for a relatively small portion of total shipments in virtually all lower tier industries -- we also eliminated the supplier industries from our mixed output and commercial sectors.

These refinements of the original sample represent an attempt to isolate the impact of market orientation on industry structure and cost distribution, and to "factor out" the effects of differences in product technology and tier position -- in short, to ensure the best "apples-to-apples" comparisons. The slide identifies each of the defense-oriented and mixed output industries for our refined sample

The lack of visibility into lower tier supplier industries is a clear limitation of the Census data. We believe that this analysis should be extended to lower tier suppliers through the use of targeted industry surveys.

Market Sectors and Product Categories

Defense-Oriented:

Aero & Elec
Military Aircraft
Guided Missiles & Space Vehicles
Search & Navigation Equip
Space Propulsion Units & Parts
Space Vehicle Equipment, nec

Mechanical
Ammunition, Except Small Arms
Ordnance & Accessories, nec
Tanks & Tank Components
Ship Building & Repairing

Mixed Output:

Aero & Elec
Aircraft Engines & Engine Parts
Aircraft Parts & Auxiliary Equip
Radio & TV Communications Equip
Electrical Equipment & Supplies, nec

Mechanical
Fluid Power Cylinders & Actuators
Turbines & Turbine Generator Sets
Small Arms

Commercial-Oriented:

45 Industries Including Civilian Aircraft, Automobiles & Computers

Industry Cost Framework

We developed a framework for comparing the distribution of industry costs among sectors and industries. Using ***Census of Manufactures*** data, we can identify the proportion of total industry costs allocated to four major industry cost categories: purchases, production payroll, non-production payroll, and "non-payroll value added" (value added less total payroll costs).

In this study, we use non-payroll value added (or NPVA) as a proxy for industry overhead. NPVA includes a range of cost elements including:

- Fringe benefits
- Capital expenditures, rental payments, and other facility costs
- Travel, communications, and other administrative expenses, and
- Profits, taxes, finance charges, and other transaction costs.

While the corporate sector typically uses a somewhat different definition of overhead (for example, the payroll costs of some management and clerical personnel are usually allocated to the overhead account), we believe NPVA is a useful, objective benchmark for comparing indirect costs across sectors and industries. This approach has been employed in previous analyses of the defense industry.[2]

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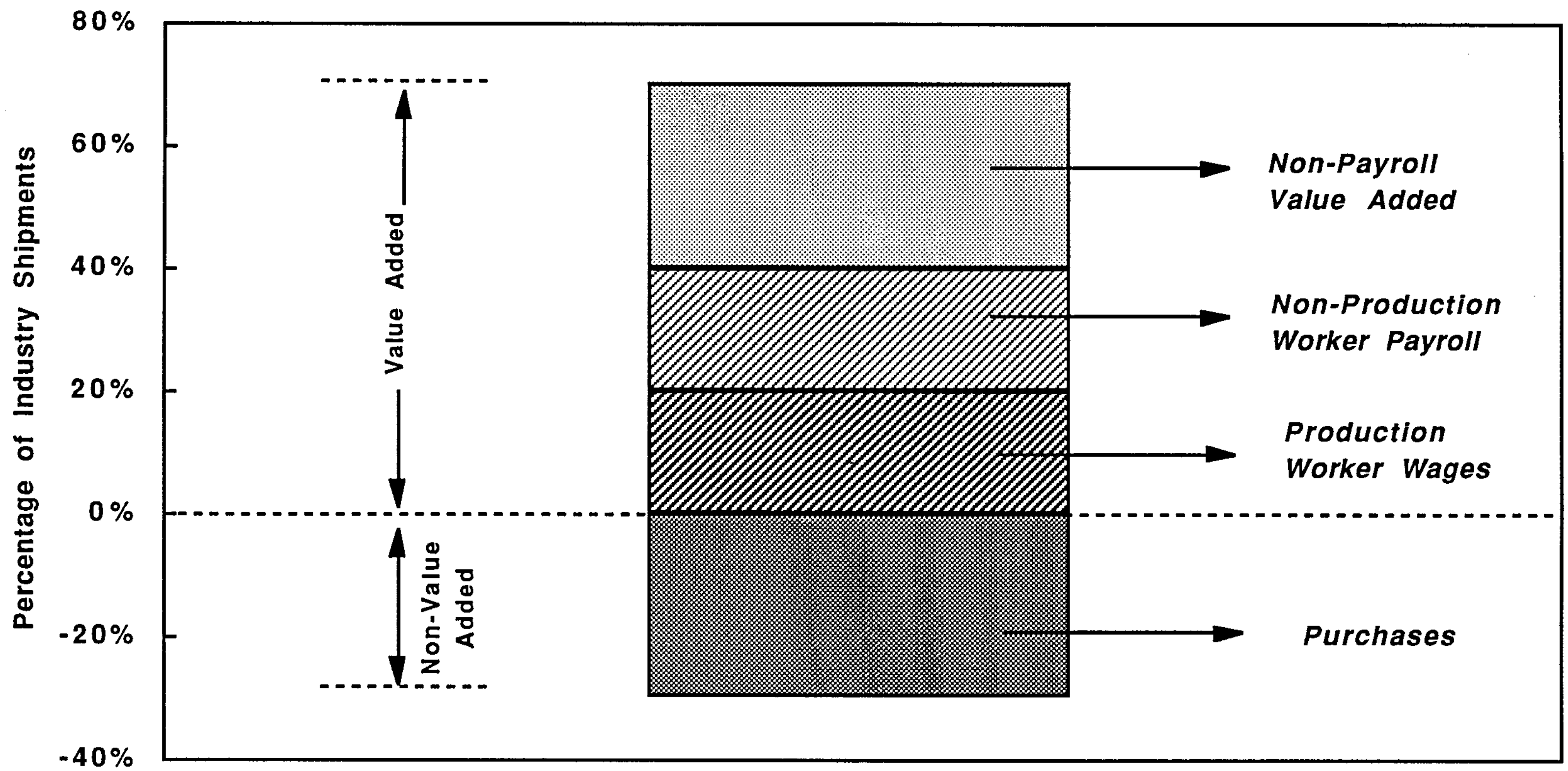
[2] Edward M. Kaitz & Associates, *Overhead Costs and Rates in the U.S. Defense Industrial Base*, October 1980.

Industry Cost Framework



Sector Trends

In this slide, we use our industry cost framework and refined industry sample to assess the distribution of industry costs for the defense-oriented, mixed output, and commercial-oriented sectors.

The top box represents the Aerospace & Electronics (A&E) product category; the lower box is the Mechanical (MECH) category. The columns on the lefthand side of each box represent the defense sector, while the middle columns represent the mixed output sector, and the righthand columns are the commercial sector.

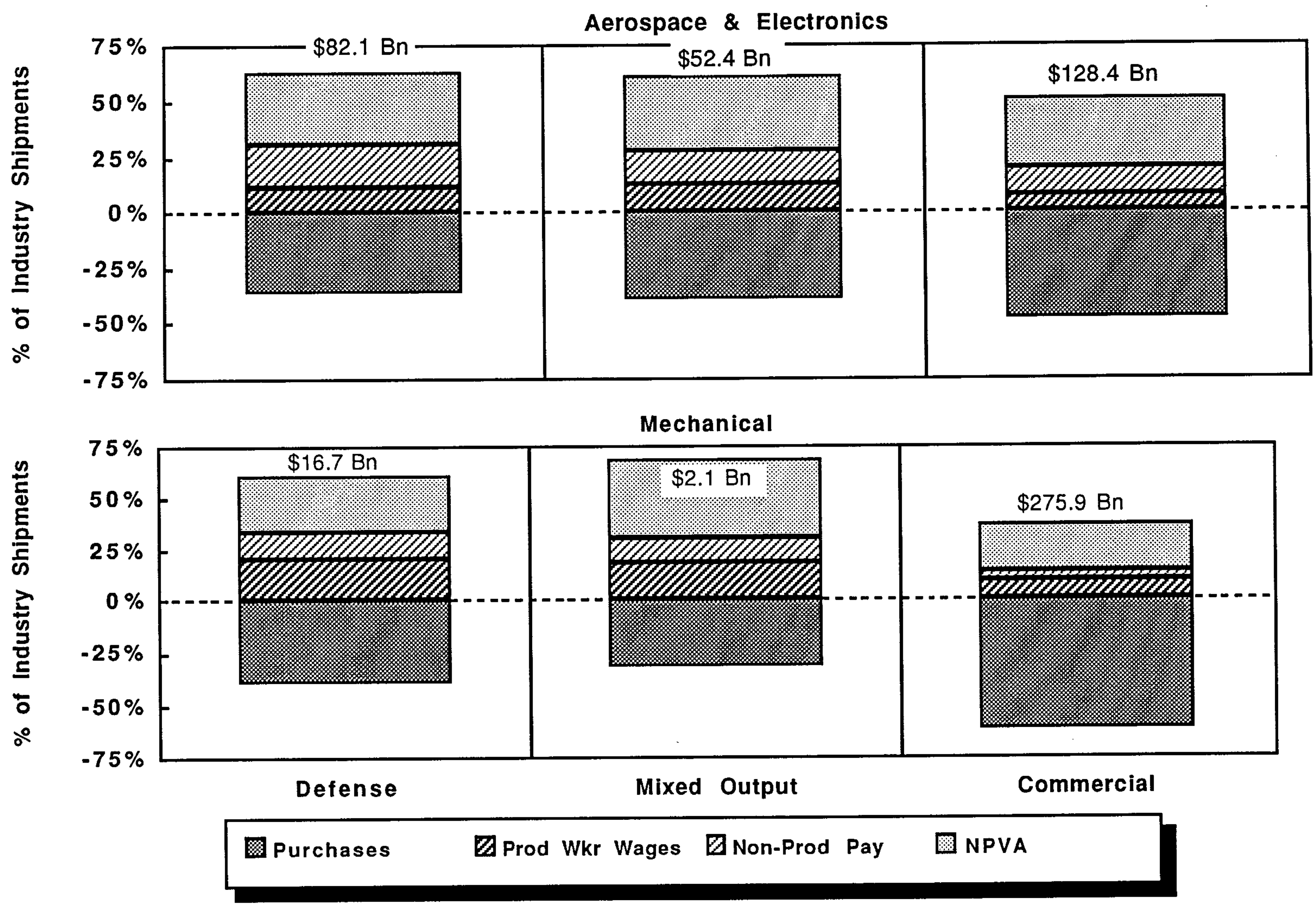
In each of the six columns, the area above the "0%" line represents value added, while the area below this line represents purchases. For every column, the sum of the four cost categories equals 100 percent of shipments. The dollar figures at the top of each column represent the total shipments of that industry sector.

This slide shows some striking trends across product categories. First, value added increases with higher levels of participation in the defense market (setting aside the small, anomalous mixed output MECH sector). As a portion of total costs, NPVA is relatively consistent across product categories -- totaling some 30 percent for A&E and 25 percent for MECH. As a percentage of value added, however, defense sector NPVA is significantly lower than that of the other sectors.

For both A&E and MECH, payroll costs increase with participation in the defense market. Nevertheless, wages and salaries in the defense sector account for only some 30 percent of industry costs. However, the *composition* of payroll costs differs dramatically between product categories: while in each of the A&E market sectors non-production workers account for the lion's share of a payroll costs, production worker wages dominate in the MECH sectors.

Finally, while the defense A&E sector accounts for over $82 billion in shipments, output of the defense MECH sector is less than $17 billion. These figures illustrate the high technology orientation of DoD acquisition.

Sector Trends



Source: Bureau of the Census, 1987.

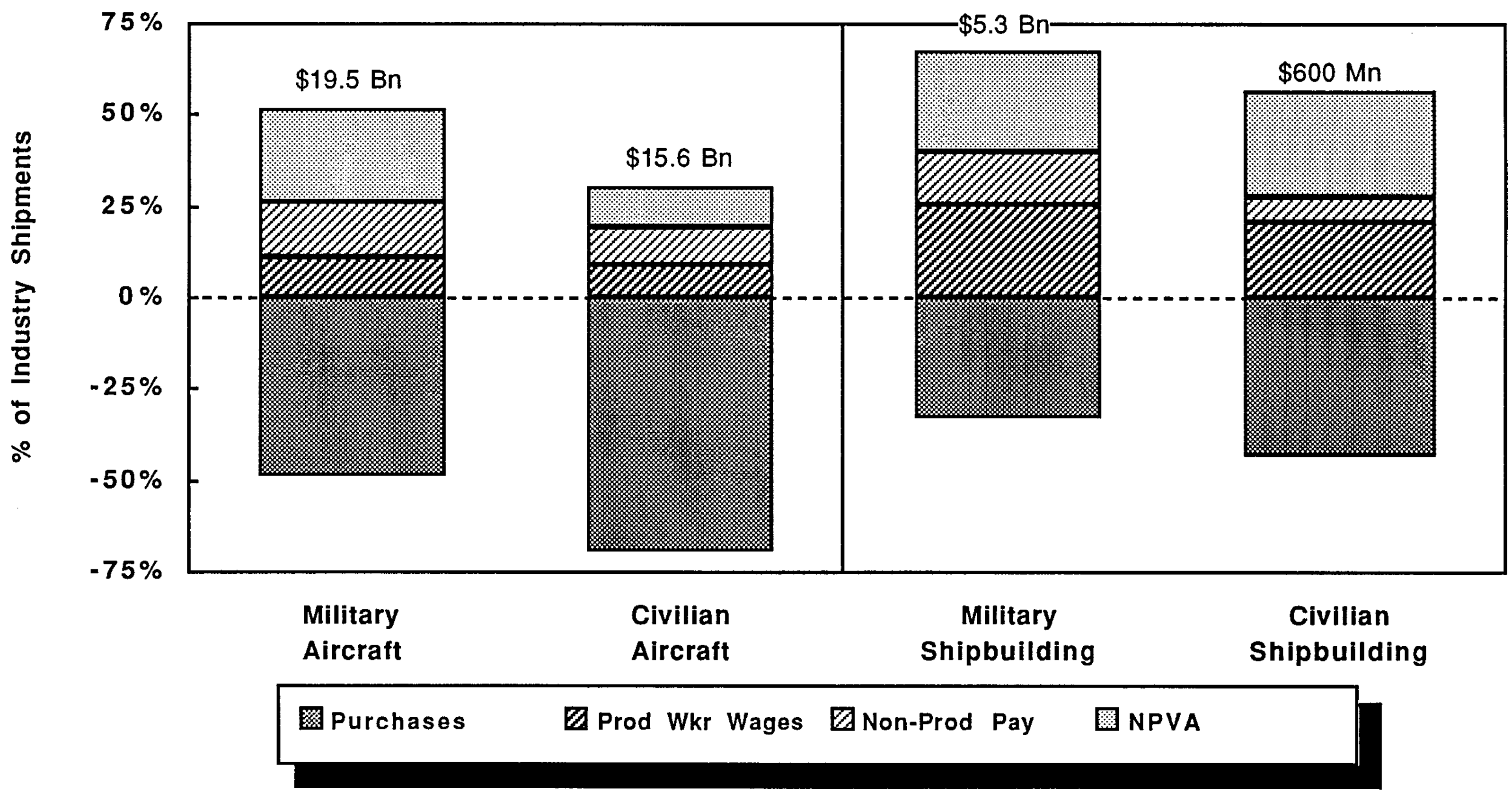
Defense vs Civilian -- Aircraft & Ships

This slide extends the cost distribution analysis from the sector to the industry level for aircraft and shipbuilding -- the two industries for which the Census publishes limited data on military and civilian components.

The data for the aircraft industry must be interpreted carefully. The Bureau of the Census applies DoD progress payments to the industry shipment account, but does not count commercial sales until the aircraft is delivered to the customer. This methodology causes a lag in the reporting of commercial aircraft sales, which appears to have suppressed NPVA costs for the civilian component of the aircraft industry.

Despite this methodological problem, the industry level data appears to confirm the trends observed at the sector level. Payroll costs are significantly higher in the military portions of both industries. Value added is higher in the military than in the civilian component of the shipbuilding industry. Finally, while non-production workers in both components of the A&E aircraft industry account for a large proportion of total payroll costs, these costs are heavily weighted toward production worker wages in both the military and civilian portion of MECH shipbuilding industry.

Defense vs. Civilian -- Aircraft and Ships



Source: Bureau of the Census, 1987.

Selected Industries

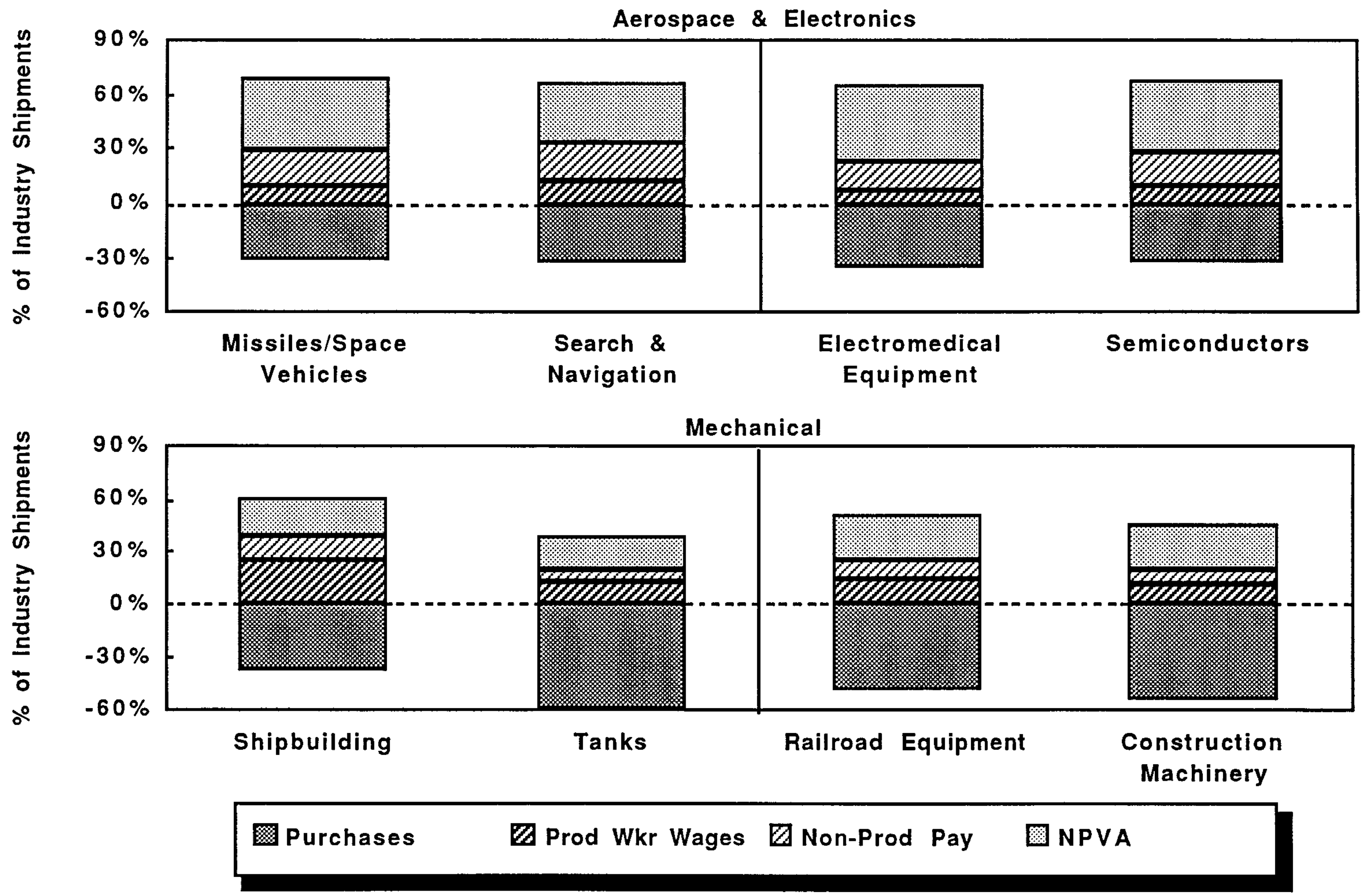
In this slide, we assess the distribution of costs for A&E and MECH defense-oriented and commercial-oriented industries that produce items of roughly comparable levels of complexity.

In the A&E category, the missile & space and search & navigation industries show striking similarities to the cost distribution pattern of the electronic component and electromedical equipment industries. We also find a rough parallelism in the MECH category between the defense-oriented shipbuilding and tank industries and the commercial-oriented railroad equipment and construction machinery industries. Finally, consistent with the sector-level trends, we find substantial differences between the A&E and MECH groupings.

While no definitive conclusions can be drawn from this small sample, these comparisons suggest that product categories, not market orientation (i.e. defense or commercial), shape industry cost distribution patterns. If this is the case, the differences in cost distribution that we observe at the sector and industry levels reflect the unique high technology orientation of defense equipment, andnot primarily the impact of the DoD acquisition environment.

Thus, our evolving hypothesis: the primary differentiating feature of the defense industry is technological and not regulatory, and that efforts to foster greater integration of the military and commercial sectors must address this technological differential, in addition to the regulatory barriers that impede access to the defense market.

Selected Industries



Source: Census of Manufactures, 1987.

Characterization of Defense and Commercial Sectors -- Workforce Composition and Costs

In this section, we turn from our analysis of the distribution of costs toward consideration of the composition of a key element of industry costs -- the industry workforce. In addition to helping us to understand the allocation of payroll costs to specific categories of workers, the analysis of workforce composition can shed considerable light on industry structure and manufacturing processes.

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Workforce Comparisons by Sector

Here, we use the industry/occupation database from the Bureau of Labor Statistics (BLS) to compare the workforce composition of A&E and MECH industries. Because the BLS data are available only at the 3-digit SIC level, the defense A&E and MECH groupings include those industry groups that provide at least 50 percent of their total shipments to Federal agencies. The defense A&E group includes search and navigation equipment, missiles and space vehicles, and aircraft. The defense MECH grouping contains ship and boat building and repairing, miscellaneous transportation (including tanks), and ordnance and accessories.

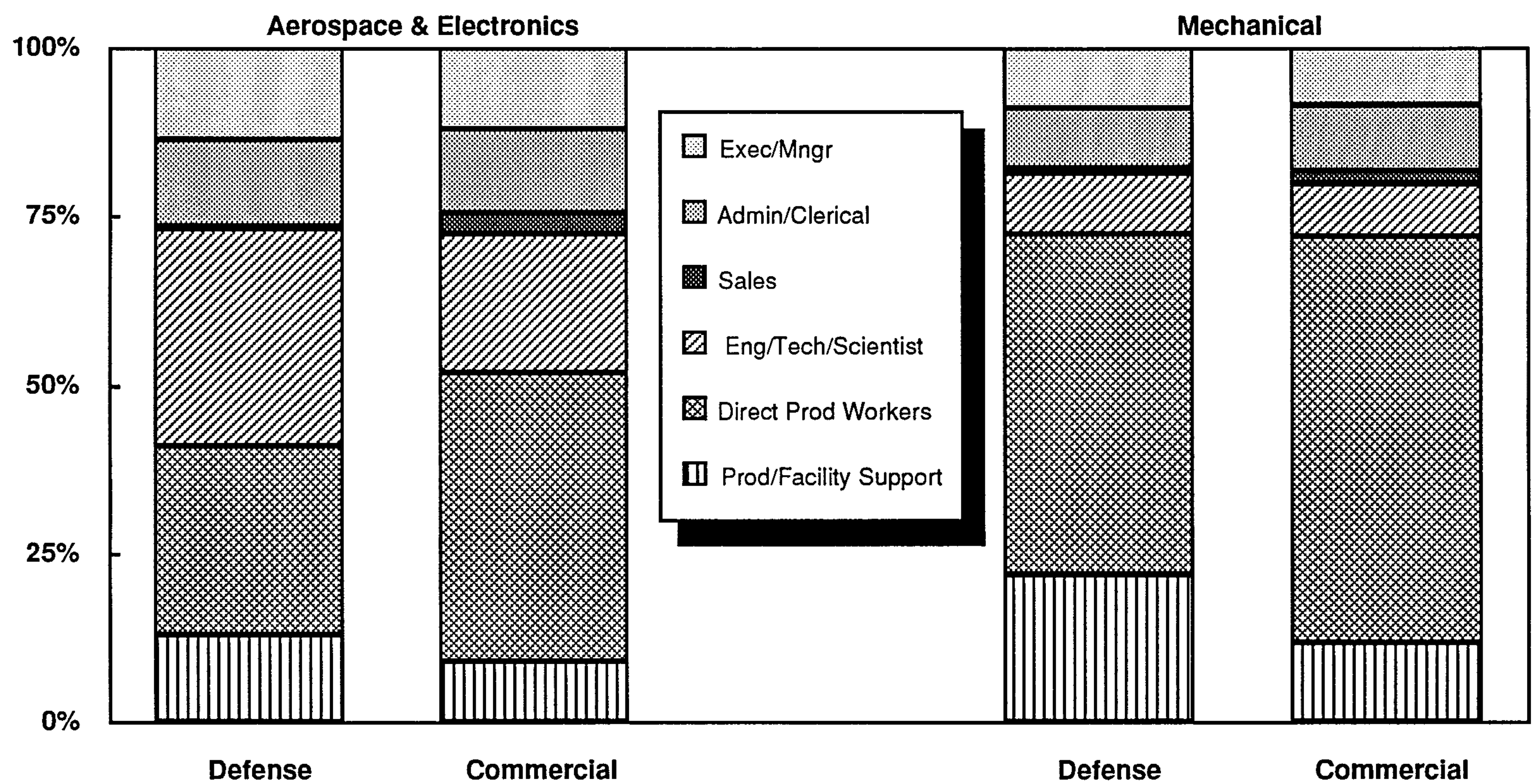
The BLS statistics highlight the striking differences in workforce composition between A&E and MECH industries. Both defense and commercial A&E industries have significantly more executives/managers and clerical personnel than their MECH counterparts. The relatively high level of administrative employment in defense A&E industries is often considered to reflect the additional costs imposed on industry by government oversight. However, as discussed later in this briefing, we believe the large "overhead" staffs in defense A&E industries are primarily a result of the strong engineering orientation of this sector.

Indeed, the chart indicates that A&E industries employ relatively large numbers of engineers, scientists, and technicians. In contrast, MECH industries are heavily weighted toward production workers. This distinction is consistent with the Census data, which indicate that payroll costs in A&E industries are heavily weighted toward the non-production workforce, while production worker wages dominate payroll costs in MECH industries. In contrast, the defense- and commercial-oriented sectors within each of the A&E and MECH industry groupings exhibit more similarities than differences. For example, the executive/managerial and administrative/clerical staffs are almost exactly the same within the two product categories.

There are also important differences in workforce composition within each of the product categories. In the A&E sector, for example, engineers and other technical personnel account for about 35 percent of the workforce in defense-oriented industries, compared to only about 30 percent production workers. In contrast, commercial A&E industries employ significantly more production workers than technical personnel. For both A&E and MECH groupings, defense industries employ fewer sales personnel than their commercial counterparts. In contrast, production support personnel -- such as inspectors, mechanics, and guards -- are somewhat more numerous in the two defense-oriented sectors.

In general, the differences between the A&E and MECH groupings appear to be more striking than the differences between the defense and commercial sectors within each product category. The BLS data therefore suggests that product technology has a stronger role in shaping workforce composition than market orientation.

Workforce Composition by Sector



Source: Bureau of Labor Statistics, 1990.

Missiles & Space Vehicles vs Home Appliances

In this chart, we have used a somewhat more detailed breakdown of the BLS occupational data to compare the workforce composition of two "extreme" examples of the defense-oriented and commercial-oriented sectors: the missiles & space vehicles and home appliances industries.

In the missile & space vehicles industry, technical personnel account for almost one half of the industry workforce, and are supported by a relatively large management and administrative staff. In contrast, only about one quarter of the workforce is employed in production-related occupations.

The home appliance workforce presents almost a reverse image. Engineering and related occupations account for less than five percent of the workforce, the management and administrative staff is relatively small, and the production workforce totals almost 80 percent of industry employment.

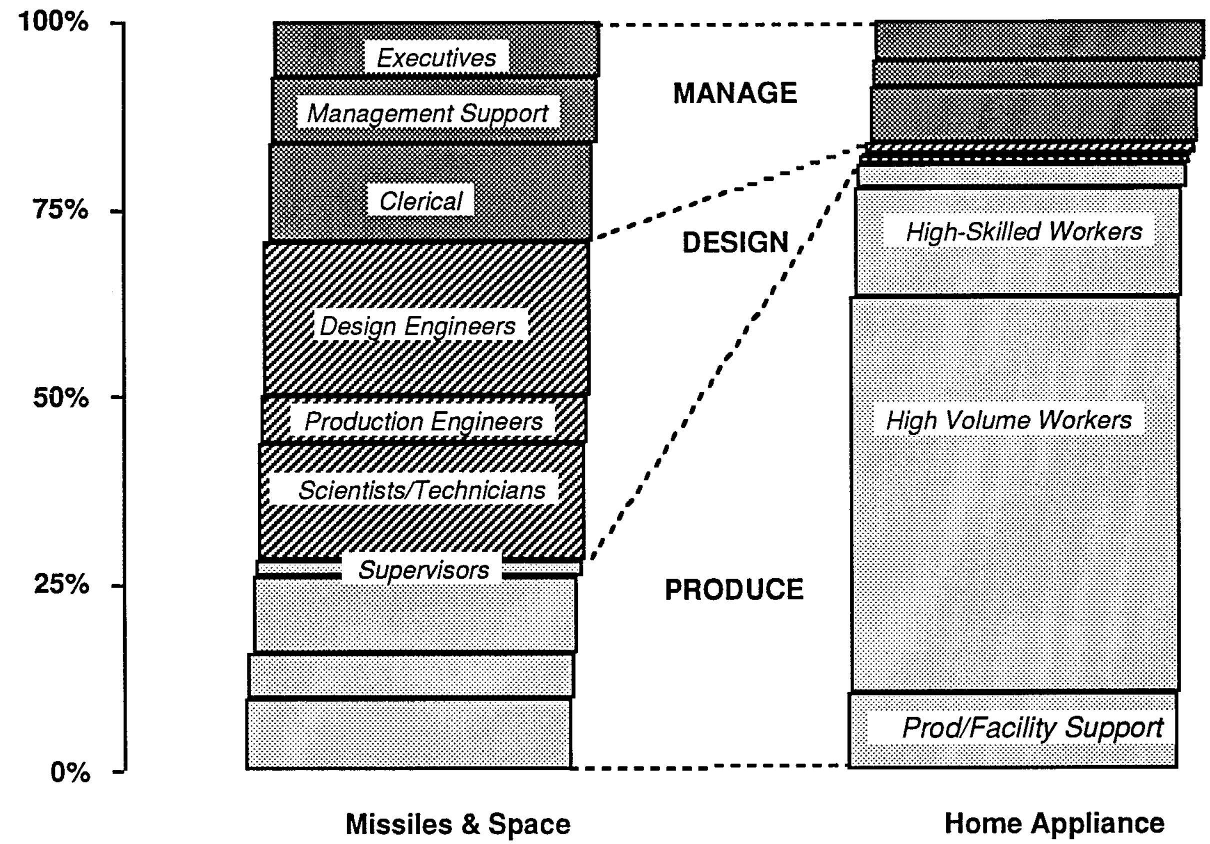
Moreover, the composition of the production workforce is dramatically different, reflecting the fundamental contrast between high volume, mass production characteristic of the commercial sector and the low volume, high precision "artisan" environment of most defense production.

In the missile & space vehicle industry, the lion's share of the production workforce is concentrated in high skill occupation categories (e.g. machinists, precision assembly) and production support (mechanics and inspectors). The vast majority the production workforce in the appliance industry operates machines that perform high speed, repetitive tasks such as stamping and automated assembly.

Two key workforce ratios drive unit costs and help account for the dramatic differentials in unit price between, say, an air-to-air missile and the common household blender: the design-to-production workforce ratio and, within the production workforce, the ratio of precision- to volume-oriented workers. When both ratios are high, unit costs will also be high.

Finally, this chart suggests that there is little compatibility in labor skills, production equipment, and manufacturing processes of these "typical" defense and commercial industries.

Missiles/Space Vehicles vs. Home Appliances



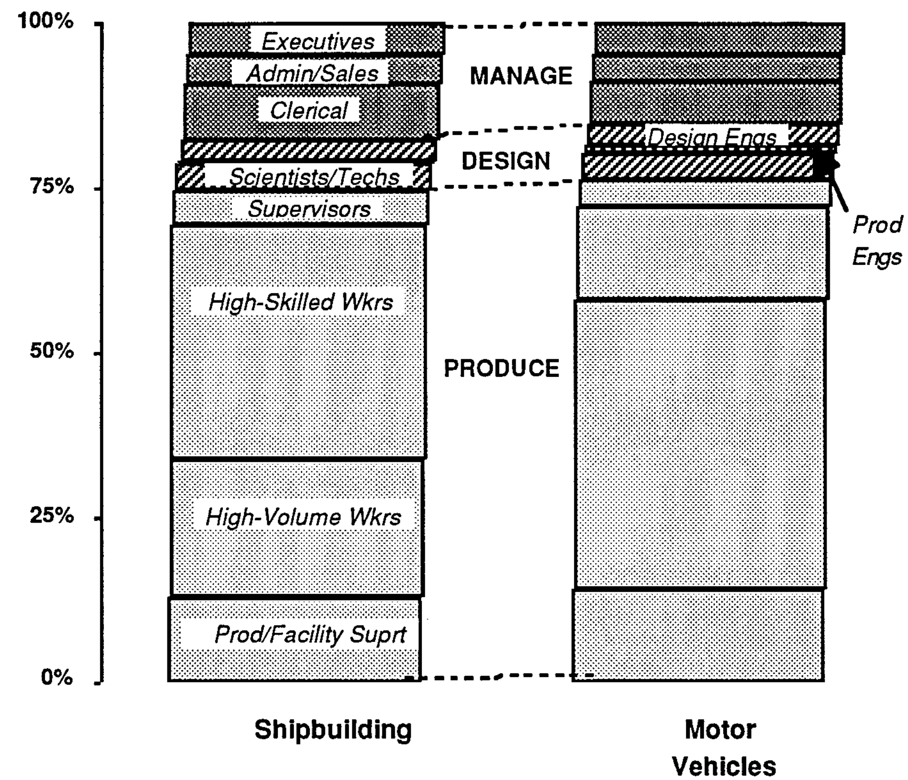
Source: Bureau of Labor Statistics, 1990.

Shipbuilding vs Motor Vehicles

In this example, we compare defense- and commercial-oriented industries with similar design-to-production worker ratios -- the shipbuilding and motor vehicle industries. As the chart indicates, these industries employ comparable proportions of managers, designers, and production workers. Nevertheless, they maintain sharply contrasting production workforces. The shipyards employ a high concentration of welders, shipfitters, pipefitters, and construction craftsman; in the motor vehicle industry, most of the production workforce is engaged in automated or semi-automated high volume assembly operations. In other words, industries that may look similar at a distance may utilize very different production processes, and therefore maintain sharply contrasting workforces.

It is important to note that the BLS workforce data for the shipbuilding industry may somewhat understate the engineering content of the shipbuilding process. Much of the U.S. Navy's design work is handled by Navy engineers or marine architectural firms. BLS classifies employees of marine engineering firms as service industry workers, and therefore excludes these workers from the shipbuilding industry.

Shipbuilding vs. Motor Vehicles



- *Some defense and civil industries have comparable "design-to-production" ratios*
- *Nevertheless, defense production workers generally are more highly skilled*

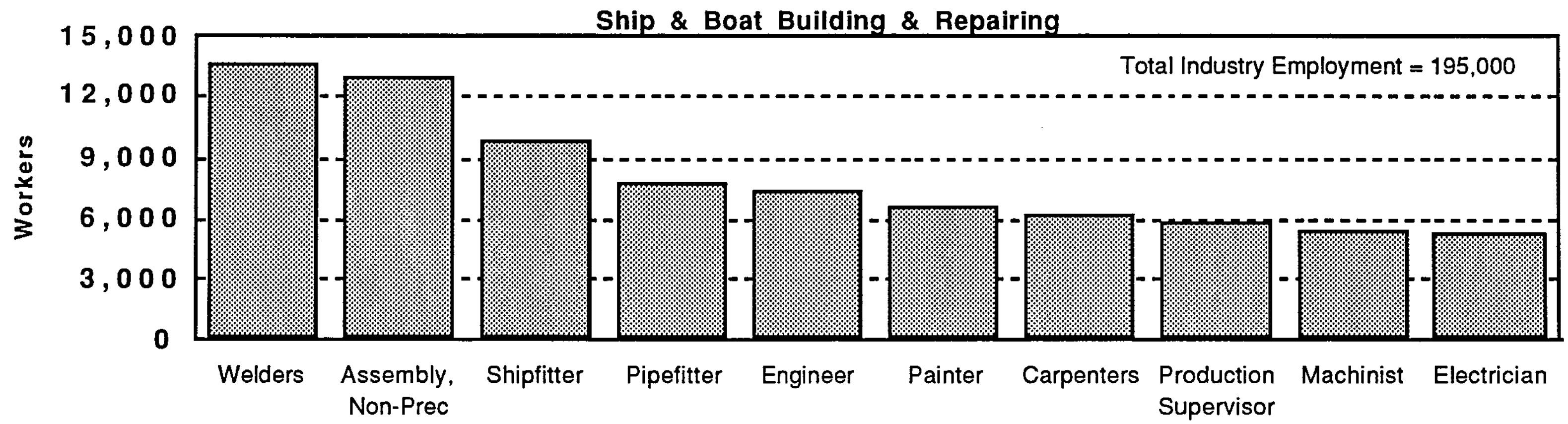
Source: Bureau of Labor Statistics, 1990.

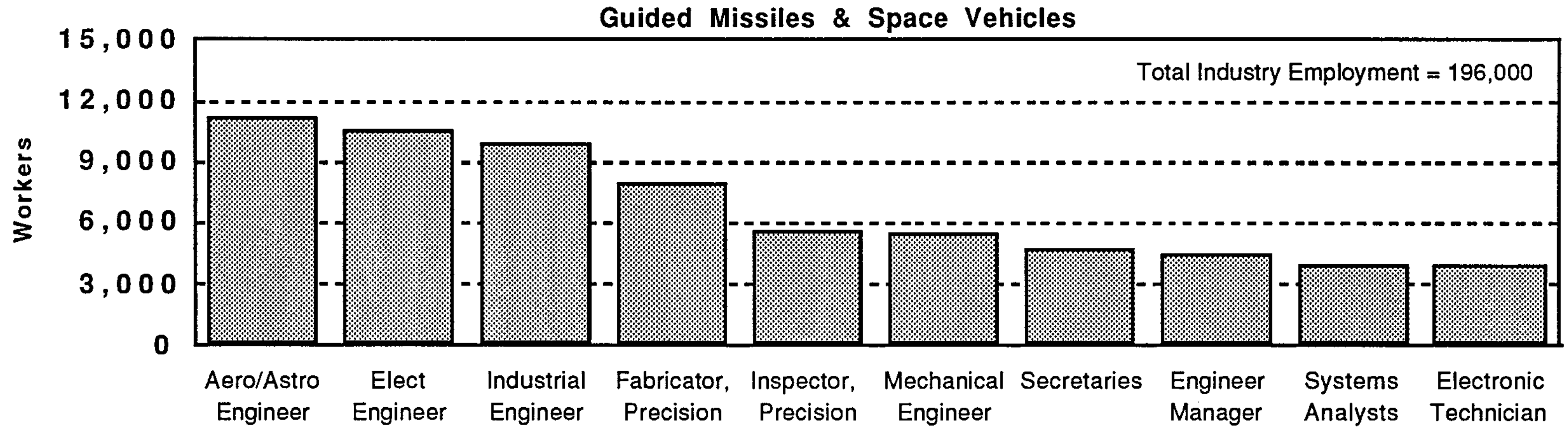
Top Ten Occupations

The nature of defense production in A&E and MECH industries is vastly different. As noted above, the shipbuilding industry is dominated by craftsman like welders, pipefitters, and carpenters (and employs more than 6000 painters!). In contrast, four out of the top six occupation categories in the missile & space industry are engineers of various disciplines. Precision inspectors are the only production-related occupation in the missile & space top ten.

This data suggest that the challenges involved in preserving critical capabilities in A&E and MECH industries are very different, and may require policy responses that are specifically targeted to the needs of each sector.

Top Ten Occupations





- *Defense sector is not monolithic; defense A&E industries have greater engineering orientation than their MECH counterparts*

Source: Bureau of Labor Statistics, 1990.

Industry Workforce Relationship

In reviewing the BLS occupational data, we noted that industries that maintain relatively large engineering staffs seem also to have proportionally more administrators. Similarly, we discovered that industries with a strong production orientation operate with lower management overhead. We developed this chart to demonstrate the strong relationship between engineering, production, and administrative employment.

The chart divides the workforce in each of the BLS sample industries into three broad occupational categories: production workers, engineering and technicians (including scientists), and administrators (executives, management support and clerks).[3] The x-axis is the proportion of production workers in the industry workforce. The y-axis is the percentage of the entire industry workforce. The series of black dots represents the proportion of production workers for each industry; the white dots represent the proportion of production workers plus the proportion of engineers. The remainder is administrative employment.

Consider, for example, the search and navigation industry. Production workers account for about 27 percent of the total industry workforce. This workforce share is represented by a black dot that is just above the "25%" horizontal line and just to the right of the "25%" mark on the x-axis. Directly above the black dot marking the industry's proportion of production workers, there is a white dot labeled "Search & Nav," representing the sum of the production and technical workforce. The area between the black and white dots represents the proportion of engineers and related personnel (about 41 percent for this industry). The remaining workers (about 30 percent) are managers, administrators, and clerks. This share is represented by the area between the "100%" horizontal line (the total industry workforce) and the white dot marking the combined production and engineering staff.

The chart shows a strong correlation between the three major occupational categories. The size of the industry technical staff falls sharply as the proportion of production workers increases. When production workers approach 80 percent of the total workforce, technical employment virtually disappears, leaving the administrative staff at about 20 percent. In contrast, if we were to extend our "best fit" line through the Y-axis -- the point at there are no production workers -- the technical staff would account for 56 percent of the industry workforce, supported by an administrative staff totaling 44 percent. Using simple algebra and the equation of our "best fit" line obtained through linear regression, we calculate that there are approximately 22 management/administrative/clerical workers for every 100 production workers, compared to about 76 support workers for every 100 engineers and related personnel. In other words, engineers require about 3.5 times more administrative support than production workers!

Finally, the chart suggests that defense-oriented industries conform fully to these workforce relationships, as the five primary defense-oriented industries lie nicely against our "best fit" line. If defense-oriented industries have relatively large administrative staffs, it appears due primarily to their strong engineering orientation, not the result of their participation in the defense market.

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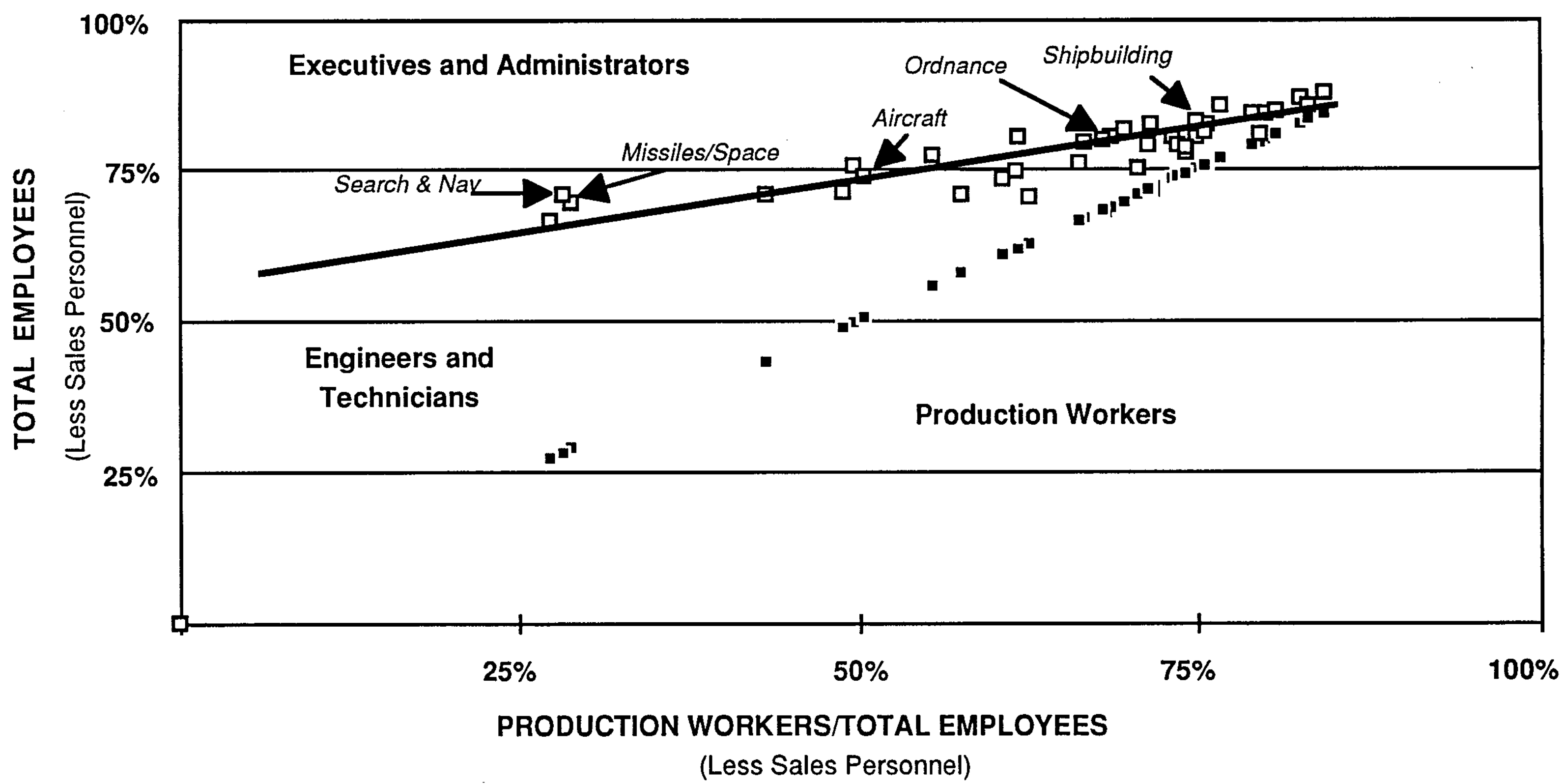
[3] For this chart, we eliminated sales-related occupations from the industry workforce totals, since the sales workforce appears to reflect market factors such as the number of customers and the product line diversity, and is not related to product technology or other technical factors.

Industry Workforce Relationship



- *Exec/admin support requirements are 3 1/2 time greater for engineers than production workers*
- *Large executive/admin staffs in defense-oriented industries reflect engineering orientation*

Source: Bureau of the Census, 1987; Bureau of Labor Statistics, 1990.

Accounting-Related Employment

Do DoD financial regulations and cost accounting standards (CAS) significantly increase acquisition costs by compelling government contractors to employ excessive numbers of accountants and related workers?

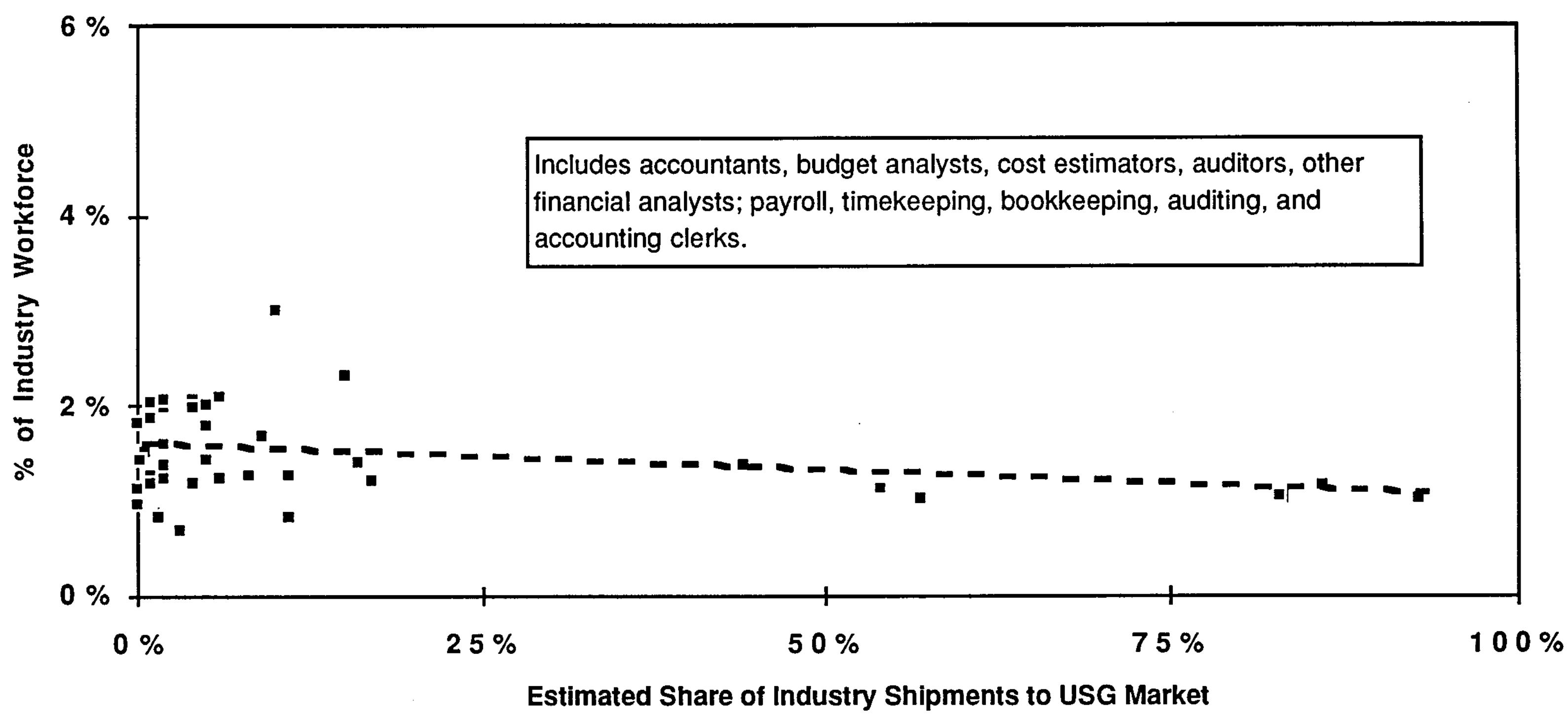
To answer this question, we plotted the proportion of accounting-related workers by level of participation in the defense market. We defined accounting-related occupations to include accountants, budget analysts, cost estimators, auditors, other financial analysts, payroll clerks, timekeeping clerks, bookkeeping clerks, auditing clerks, and accounting clerks.

For virtually every industry group, accountants and related occupations account for only one to two percent of total industry employment. The computer industry is a noteworthy outlier with three percent of its workforce engaged in accounting-related occupations. The accounting-related staff of the six defense-oriented industry groups totals one to 1 1/2 percent of the total workforce. If anything, accounting-related employment trends slightly <u>downward</u> with increasing defense market participation.

This slide suggests two conclusions: 1) while DoD financial controls and other oversight regulations may have other harmful effects on contractor costs or operations, DoD accounting requirements do not appear to result in noticeably higher levels of accounting-related employment in the defense sector, and 2) in any case, accounting-related employment accounts for a relatively small proportion of the industry workforce and, therefore, is not a primary cost driver in defense acquisition.

It is important to note that the BLS data provides an occupation-based measurement of workforce composition. While presumably there is a strong correlation between occupations and activities, it is possible that significant numbers of defense workers who are not accountants devote a substantial portion of their time to financial recordkeeping and other related tasks. In fact, CAS requirements and similar regulations may play an important role, along with performance requirements and other factors, in driving up the proportion of engineers and other technical personnel in the defense sector. This explanation potentially reconciles the apparent contradiction between the BLS data and the long-standing complaints of defense contracts that DoD accounting requirements add substantially to their production costs. We recommend that, to resolve this important issue, DoD conduct an activity-based assessment of the engineering workforce in the defense and commercial sectors.

Accounting-Related Employment



• *Accounting-related employment is comparable in defense- and commercial-oriented industries*

Source: Bureau of the Census, 1987; Bureau of Labor Statistics, 1990.

CSIS Case Study

In March 1991, the Center for Strategic and International Studies (CSIS) published the report, ***Integrating Commercial and Military Technologies for National Strength,*** which argued for substantial reform in DoD acquisition regulations. The report included a case study comparing the administrative staffs of defense and commercial facilities.

The case study data was provided by a major U.S. aerospace company with segregated defense and commercial divisions. Workforce levels for broad occupational categories were provided for both divisions. Administrative employment (i.e., finance, material, contracts, general management, planning and control, industrial relations, program management, business planning, sales and marketing, legal and government affairs) in the military division was 18.2%, but only 8.5% in the commercial division.

The report concluded that the difference in the size of administrative staffs was a function of the market orientation of the two divisions, and that the "extra" administrative workers in the defense division were needed to ensure compliance with DoD acquisition regulations. The report did not consider whether non-market factors such as engineering intensity might be primarily responsible for the differential in the size of the divisions' administrative staffs.

Using the BLS data, our approach now allows us to differentiate the impact of market and technology factors on workforce composition. In the following slide, we attempt to incorporate the CSIS case study data into our analytic framework.

CSIS Case Study

Occupation Category	Military Division	Commercial Division
Administration	9,979	3,842
Other	629	170
Engineering	13,605	7,557
Computing	5,425	1,211
Manufacturing	18,306	25,548
Quality Control	2,583	2,835
Logistics	1,399	1,696
Facilities	3,038	2,177
TOTAL	45,866	54,335
Administration	**18.2%**	**8.5%**

Source: CSIS, 1991.

Reconciling Case Study and Industry Data

In order to incorporate the case study data in our analysis, we converted the occupation figures into our framework. We assigned manufacturing, quality control, facilities, and logistics to our "Production Worker" category. Engineering and computing make up our "Engineering, Scientists, and Technicians" category. Finally, we put administration and "other" into our "Executive, Management Support, and Clerical" pool.

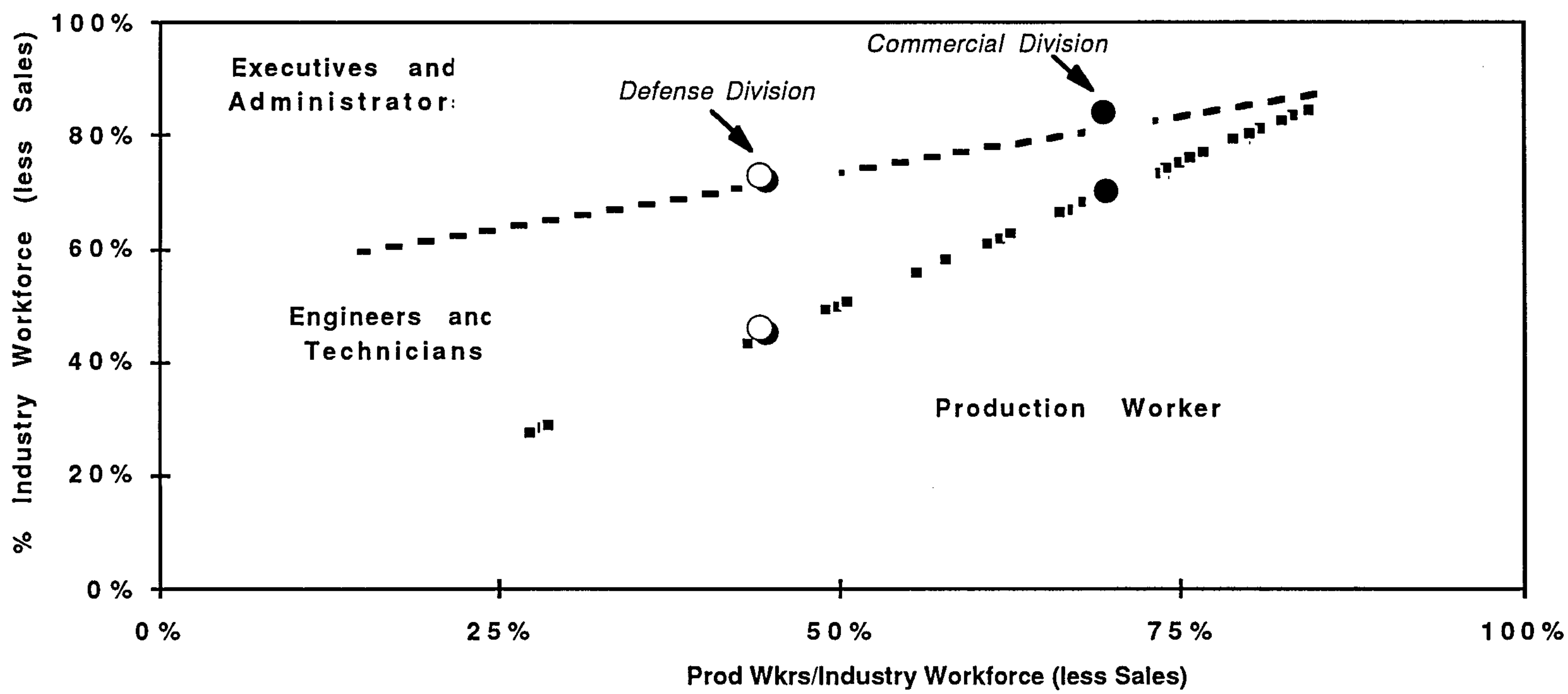
In reviewing the case study figures, we discovered that some of the clerical staff was buried in the engineering and computing categories of the two divisions. Using our BLS profile of the aircraft industry to estimate the size of the clerical support staff for these functions, we removed these workers and assigned them to our "Executive, Management Support, and Clerical" group. Our calculations result in the following workforce composition estimates for the two divisions:

	Military	Commercial
Exec, Mgmnt Support, Clerical	28%	14%
Engineering, Scientists, Technicians	26%	15%
Production	46%	71%
	100%	100%

The military division falls right on the estimated trend line, while the commercial division is slightly above (in other words, the commercial division has slightly fewer executives, etc. than we would expect given its engineer, etc.: production worker ratio). Thus, the difference in the size of the administrative staffs appears to be largely -- if not completely -- the result of the engineering orientation of the two divisions. This finding appears to support a substantial reinterpretation of the CSIS case study results.

Why does defense require so many more engineers than the commercial sector? Certainly, performance requirements and DoD's strong orientation toward aggressive technology development probably play a strong role. However, defense acquisition also imposes on defense contractors a variety of testing and technical documentation requirements that may reflect primarily in higher employment levels for engineers and related personnel. If so, efforts to reduce defense acquisition costs should shift from the traditional focus on administrative employment in exchange for a new emphasis on the impact of the regulatory environment on engineering requirements. As noted above, an activity-based assessment of engineering time utilization is needed to determine the impact of DoD regulations on the defense engineering workforce.

Reconciling Case Study and Industry Data



Source: CSIS, 1991; Bureau of the Census, 1987; Bureau of Labor Statistics, 1990.

Payroll

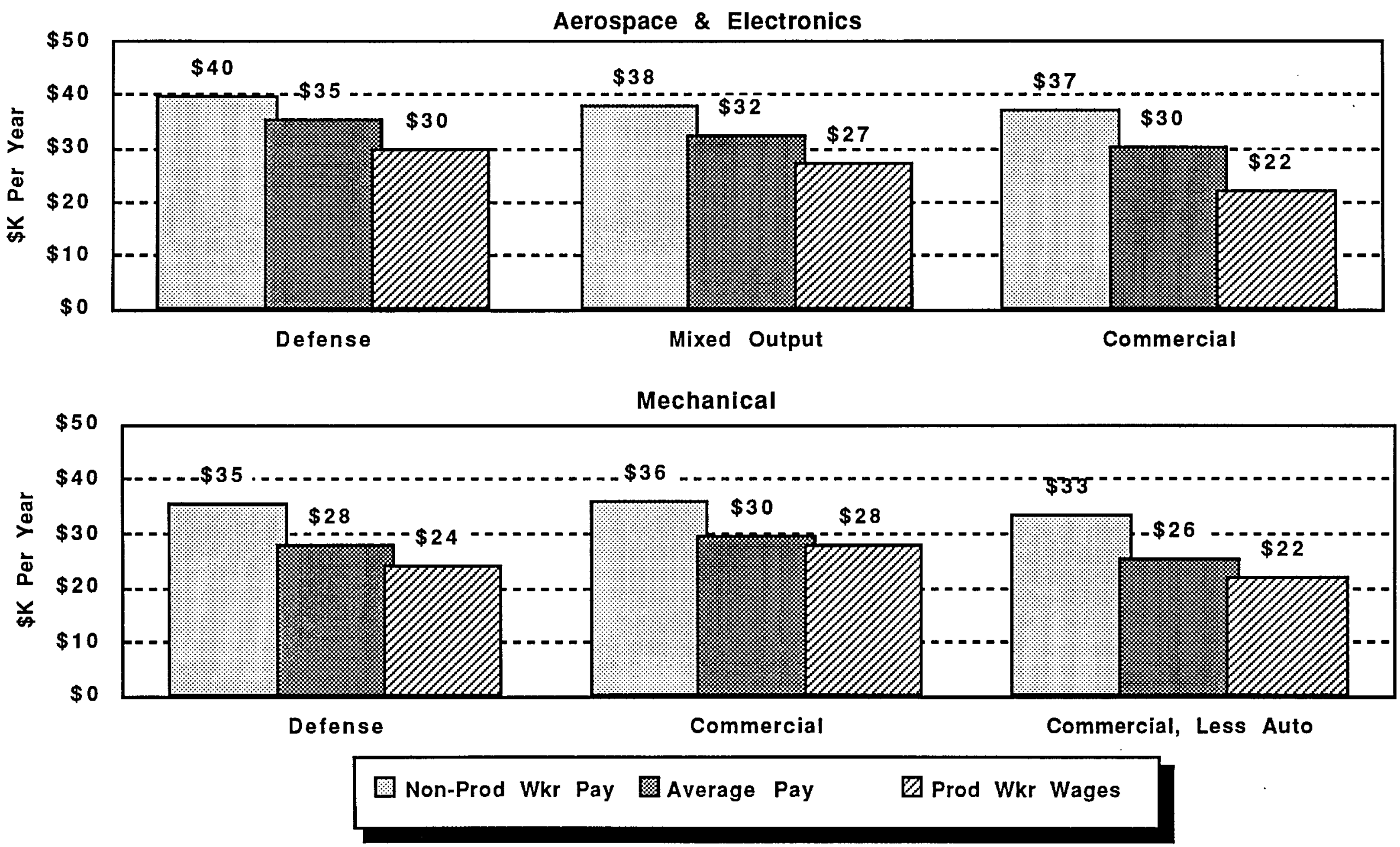
This chart compares average employee, white collar worker, and production worker pay for our refined defense-oriented, mixed output, and commercial-oriented industry groups. In 1987, average annual pay was about $31,000 for employees of commercial-oriented industries, $34,000 for employees of mixed output industries, and $36,000 for defense sector employees. In other words, average pay rises with increasing participation in the defense market. This trend reflects in part the predominance of engineers and other well-paid white collar workers in the defense sector.

Higher average wages in the defense sector are also the result of the relatively high wages earned by defense production workers. In 1987, defense blue collar workers averaged about $30,000 per year, compared to only some $22,000 earned annually by production workers in the commercial sector. This differential is driven primarily by the relatively high concentration of precision workers, craftsmen, and repair specialists in the defense workforce. According to 1991 BLS industry wage surveys, the average hourly wage of these highly skilled workers ($13.59) is more than 40 percent higher than the wages paid to machine operators and assemblers ($9.67), who account for a large portion of the production workforce in the commercial sector.

In contrast, white collar pay was relatively consistent across market sectors -- nearly $40,000 for the defense and mixed output industry groupings, only slightly less for the commercial sector.

In summary, the defense sector appears to pay higher salaries and wages than its commercial counterpart because it employs a higher proportion of white collar professionals and skilled production workers. This analysis suggests that defense-oriented industries may achieve significant payroll savings through more extensive use of enterprise integration (EI) technologies that improve the efficiency of the engineering process, as well as flexible manufacturing equipment that reduces requirements for precision craft, trade, and assembly workers.

Payroll



Source: Bureau of the Census, 1987.

Fringe Benefits

In general, defense-oriented industries provide somewhat better fringe benefits to their employees than the mixed output and commercial sectors in the same product category. In the A&E category, for example, the defense sector contributes almost $7,600 per employee, compared to about $7,400 for mixed output and $6,200 for commercial-oriented industries.

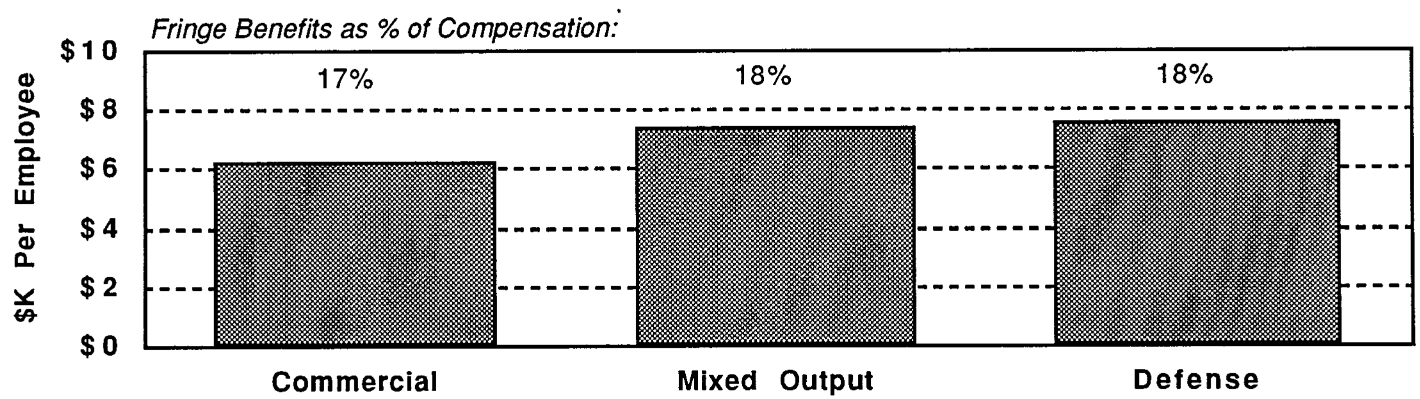
A similar trend is evident in the MECH sector, albeit with one important outlier. Defense-oriented MECH industries provide about $7,000 per employee in fringe benefits; both the small mixed output sector and the non-automotive commercial sector contribute about $6,500 in fringe benefits. The outlier, of course, is the automotive-related industries, whose extensive fringe benefits drive up the commercial sector average. For example, fringe benefits in the automobile assembly industry totaled $12,300 in 1987. The high level of unionization in automotive-related industries probably contributes to the generous fringe benefits in this sector.

Although the value of fringe benefits paid appears to increase with higher levels of participation in the defense market, this trend seems to be largely a function of the higher compensation of defense workers. As a percentage of total compensation, fringe benefits are remarkably similar within product categories (again, leaving aside the automotive sector).

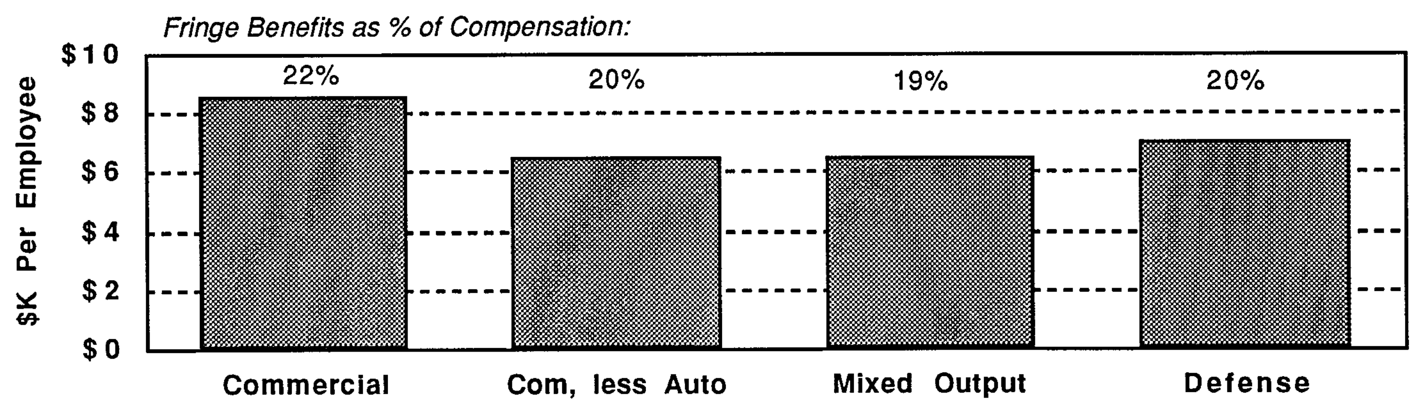
Finally, It is interesting to note that, while A&E industries appear to provide somewhat better fringe benefits in value terms (i.e., dollars per worker), fringes generally are higher as a percentage of total compensation in the MECH sector.

Fringe Benefits

Aerospace & Electronics



Mechanical



Source: Bureau of the Census, 1987.

Characterization of the Defense and Commercial Sectors -- Industry Structure and Manufacturing Processes

Using our industry-level data sources, we can also characterize the industry structure and manufacturing processes of the defense and commercial sectors. The following slides compare the average plant size, depreciable assets, rate of introduction of selected advanced manufacturing technologies, and machine tool inventory composition and age for our defense- and commercial-oriented industry groupings.

Briefing Organization

- **Introduction**
- **Characterization of Defense and Commercial Sectors**
  - -- Cost Distribution
  - -- Workforce Composition And Costs
  - -- **Industry Structure And Manufacturing Processes**
  - -- Comparative Assessment Findings
- **Federal Agency Data Sources**
- **Annex I: Defense Procurement/Industry Cost Translator (DEPICT)**
- **Annex II: Conversion of Industry (COIN) Model**

Plant Size By Employment

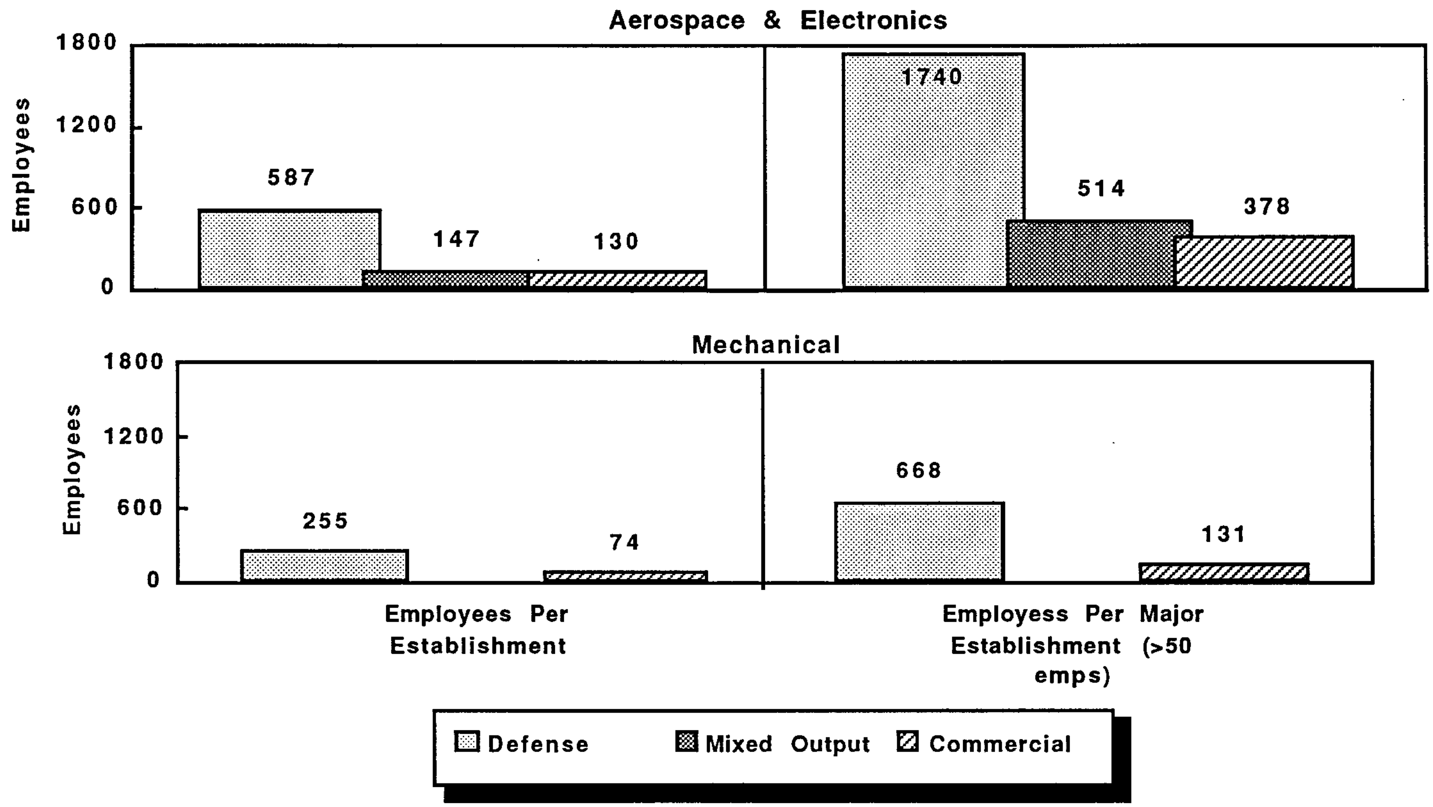
This slide indicates that, for both the A&E and MECH product categories, establishments in defense-oriented industries employ, on average, about three to five times more workers than plants in commercial-oriented industries. This differential holds even if one counts only "major establishments," discarding the "mom and pop" job shops that employ fewer than 50 workers.

Average plant size also varies strongly by product category. For both the defense- and commercial-oriented industry groupings, plants in the high-tech A&E industries have on average two to three times more employees than their counterparts in the relatively low-tech MECH groupings. For example, each major establishment in A&E defense industries employs an average of 1740 workers, compared to only 668 for major establishments in MECH defense industries.

There is no definitive explanation for this phenomenon. It is possible that plant size is a general indicator of the process complexity involved in the design and production of the relevant end item. This hypothesis would account for the differences in average employment for plants in the high-tech A&E and low-tech MECH industries, and provide a credible explanation for the disproportionate size of defense-oriented plants in both the A&E and MECH groupings (i.e. defense production is highly complex). Alternatively, the striking differential in average employment for plants in defense- and commercial-oriented industries may reflect regulatory or other non-technological factors. For example, the costs associated with establishing a secure facility or qualifying a new production line may encourage firms to concentrate its workforce in the minimum number of facilities.

In any case, plant size represents a significant potential constraint to industrial conversion and civil-military integration. Because of overhead costs, the large establishments that dominate defense-oriented industries may find it difficult to shift efficiently to the production of commercial products that are typically designed and produced in smaller establishments. Similarly, scale may also be a significant problem for commercial-oriented firms that seek to manufacture military equipment. Moreover, the plant size disparities may point to an even more fundamental barrier to the greater integration of defense and commercial productive sources -- the highly specialized, complex, and technologically advanced nature of most defense production.

Plant Size By Employment



On average, plants in defense-oriented industries are larger than their commercial counterparts

Source: Bureau of the Census, 1987.

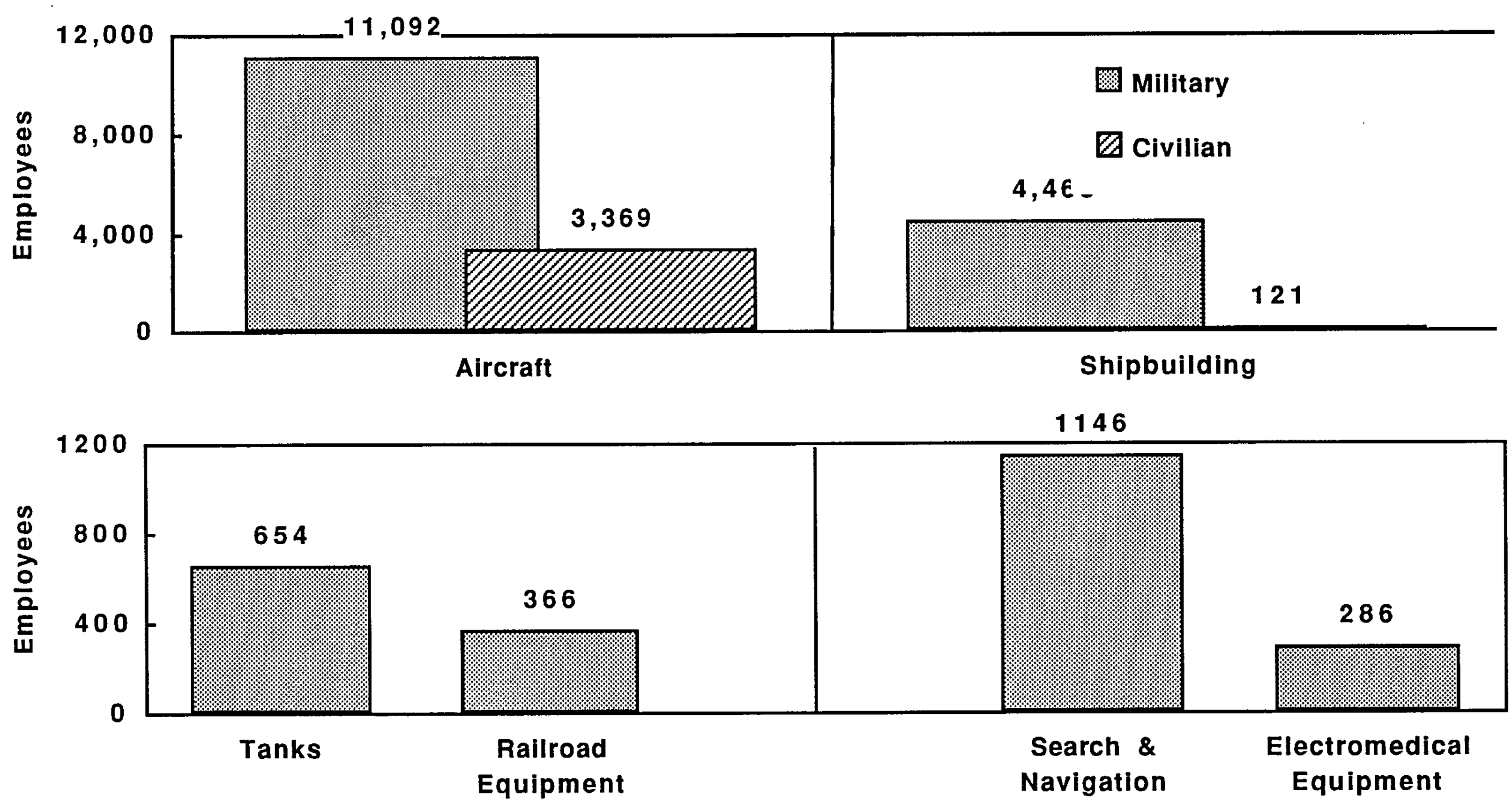
Plant Size by Employment -- Selected Industries

The Census data allows plant size comparisons for the defense and commercial sectors of both the aircraft and shipbuilding industries -- a distinction made at the 5-digit SIC level. In each case, defense establishments dwarf their commercial counterparts in average plant size.

Of course, in both aircraft and shipbuilding, the defense and commercial product may be vastly different. For example, while military shipyards build aircraft carriers and nuclear submarines from the keel up, commercial shipyards mostly perform maintenance on merchant vessels; the commercial aircraft industry includes many facilities that produce small craft for the general aviation market. Therefore, it would be useful to make plant size comparisons between defense and commercial facilities that produce more comparable products -- such as military vs. civil transport aircraft.

We have also included plant size comparisons for two pairs of so-called "related" industries, industries that utilize somewhat similar components and/or production processes and which might appear to have some civil/military integration potential. In both cases, the defense-oriented industry (tanks and search & navigation) boasts on significantly larger plants on average than their commercial-oriented partner (railroad equipment and computers).

Plant Size By Employment -- Selected Industries



Source: Bureau of Census, 1987.

Depreciable Assets

This slide compares capital intensity in the defense, mixed output, and commercial sectors for both the A&E and MECH product categories. Our measurement of capital intensity is book value of gross depreciable assets per employee, a ratio that can be calculated from the Census data.

For both A&E and MECH product categories, capital intensity diminishes with increasing participation in the defense market: while assets per employee total about $45,000 for A&E and commercial MECH industries, this figure is only about $32,000 for defense A&E and $25,000 for defense MECH.

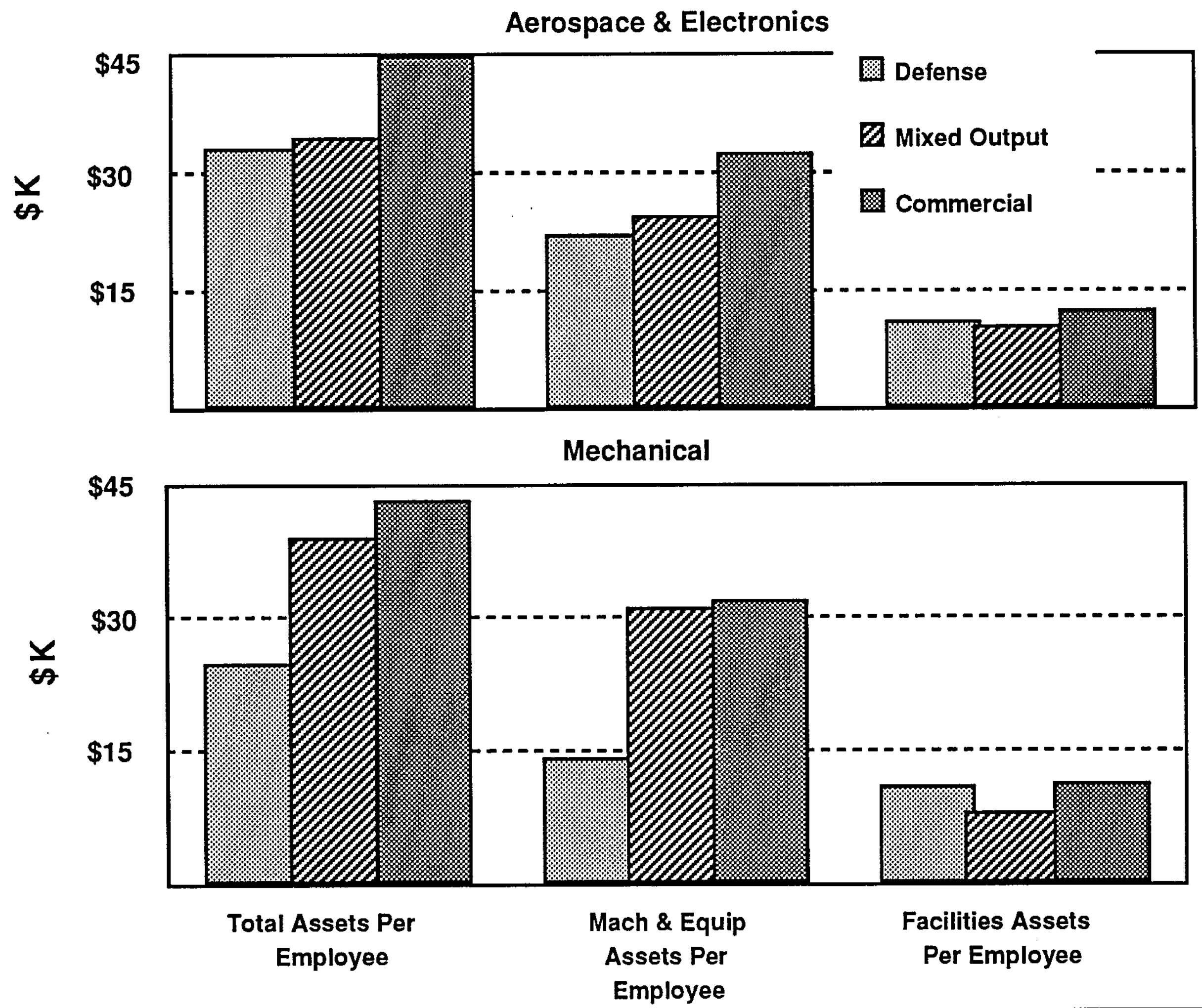
Machinery and equipment account for almost all of this differential. While commercial-oriented industries have invested about $30,000 of gross depreciable assets per employee in machinery and other equipment, defense A&E and MECH industries have dedicated only about $20,000 and $15,000, respectively. In contrast, facilities assets are largely consistent across both market and product category lines at about $10-12,000 per employee.

Our analysis of workforce composition in the defense sector provides an explanation for this apparent investment gap in machinery and other equipment. As noted earlier, defense-oriented industries generally maintain a relatively small production workforce in comparison to the commercial sector, largely because of low production rates and the complex design process for military equipment. Moreover, a disproportionate share of defense production workers are devoted to precision hand operations, such as precision assembly or specialty welding. The relatively small size and precision orientation of the defense production workforce reduces requirements for investment in machinery and other equipment.

An alternate explanation for the machinery asset gap -- that the defense acquisition environment discourages defense firms from modernizing their facilities -- is not fully consistent with the following slides, which suggest that the defense machine inventory may be newer and more capable than its commercial counterpart. In other words, the defense industry appears to have a relatively small pool of advanced machinery and equipment.

There are two significant qualifications to the data presented in this slide. First, book value does not take into account depreciation of the asset or the impact of inflation over time. Second, the asset data does not include government-owned, contractor-operated (GOCO) equipment. These limitations of the data may tend to overstate somewhat the asset gap described above.

Depreciable Assets



- *Capital intensity diminishes with increasing defense orientation*

Source: Bureau of the Census, 1987.

Manufacturing Technology

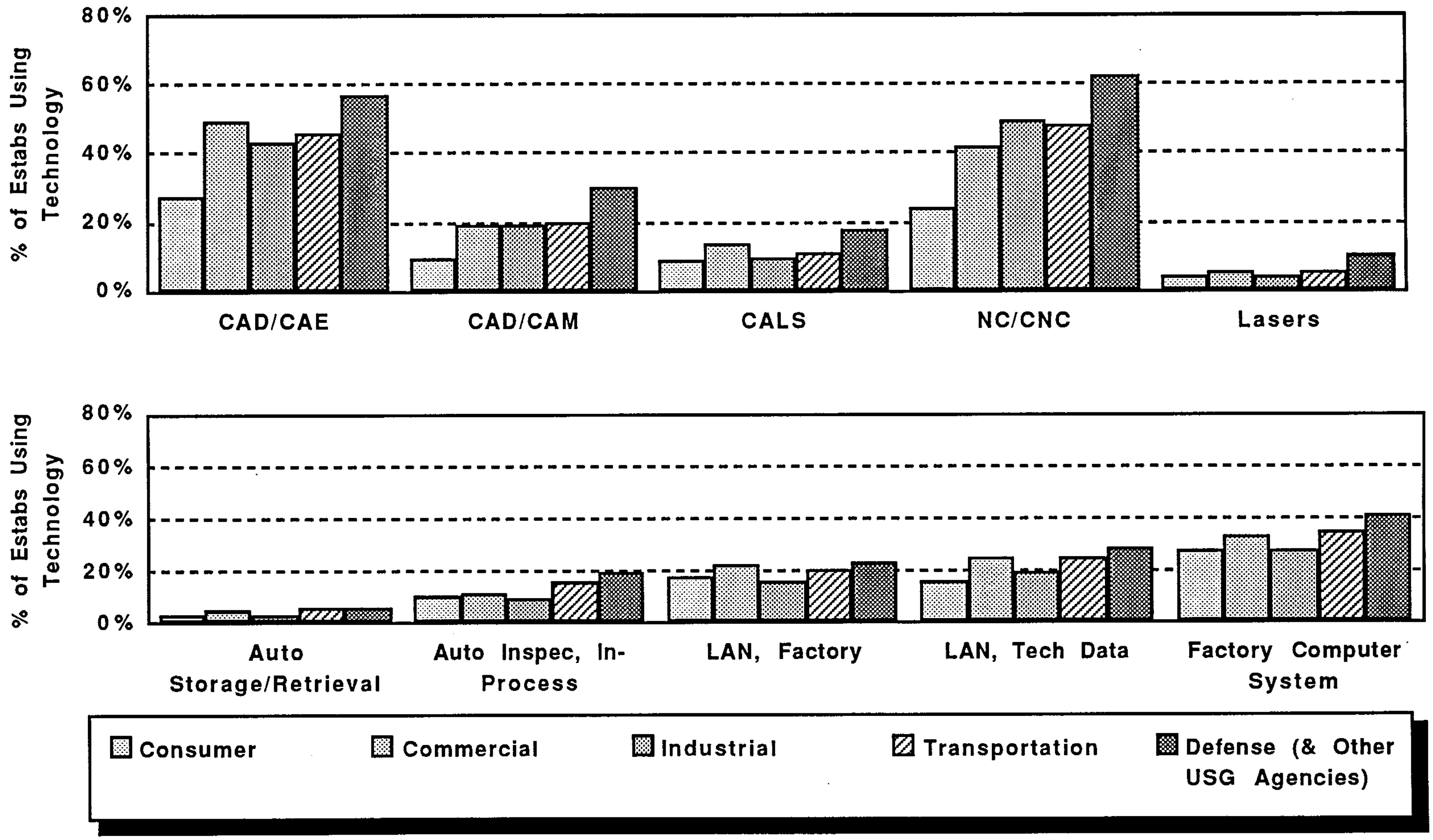
In 1988, the Bureau of the Census surveyed approximately 40,000 manufacturing establishments to assess the level of utilization of 16 advanced manufacturing technologies in various market sectors. The results of this survey are summarized in the Census publication ***Manufacturing Technology 1988***. The survey indicates that the defense industry leads other market sectors in the introduction of several key process technologies.

Establishments that manufacture items primarily for DoD and other Federal agencies were more likely than plants in other market to utilize 11 of the 16 advanced manufacturing technologies surveyed. The slide identifies ten of the technological areas in which defense-oriented establishments lead their counterparts in the consumer, commercial, industrial and transportation markets. (The technology labeled "CALS" refers to the use digital representations of computer-aided design (CAD) in procurement activities.) The eleventh such technology is automatic inspection for final products; 23 percent of all defense-oriented establishments reported utilization of this technology.

Of the five other technological areas, defense lagged significantly only in intercompany computer networks. In the defense sector, such networks were utilized in 13.9 percent of all establishments, compared to 32.6 percent for the transportation sector. Defense trailed the leaders only slightly in flexible manufacturing systems, pick & place robots, other robots, and programmable controllers.

There is one noteworthy limitation of this data. The survey does not measure the extent of technological penetration in any given establishment. Thus, a facility with a single CAD/CAE system is given the same weight as an establishment with three dozen of these machines.

Manufacturing Technology



Source: Bureau of the Census, 1988.

Machine Intensity

Here, we utilize a new database -- the ***American Machinist 14th Inventory of Metalworking Equipment*** -- to highlight the specialized nature of many defense-oriented industries. This inventory is based on a 1989 survey of approximately 10,000 establishments, and provides detailed information on some 155 stationary machines for about 150 industries at the 4-digit SIC level.

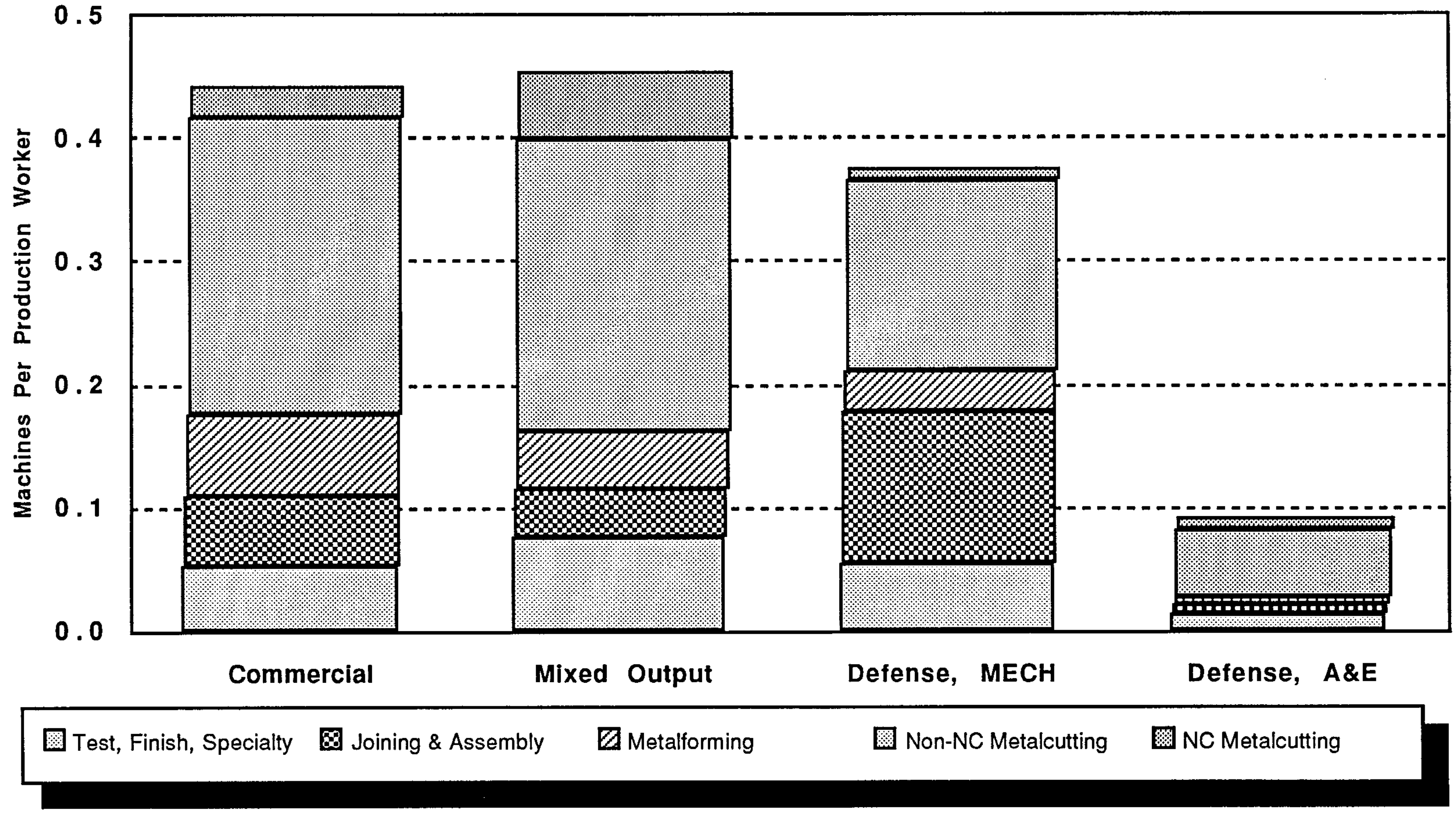
We used the ***American Machinist*** data and the Census production workforce figures for 1989 to determine the machine intensity (i.e., the number of machines per production worker) for defense-oriented, mixed output, and commercial-oriented durable goods manufacturing industries. This slide indicates that defense A&E industries have a very low level of machine intensity -- there is only about 0.1 machines for each production worker, compared to about 0.45 machines per worker in commercial-oriented industries. Moreover, the defense A&E machine inventory is concentrated heavily in metalworking equipment, and shows few machines in the metalforming and joining and assembly categories. This low level of machine intensity and metalworking concentration reflects the low volume, high precision orientation of this sector.

Defense MECH industries utilize about 0.38 machines per production worker -- somewhat fewer than the average for commercial-oriented industries, but significantly more than their A&E counterparts. The strong predominance of joining and assembly equipment reflects the widespread use of welding machines in the ship building and tanks, two important defense MECH industries.

The mixed output sector utilizes slightly more machines per production worker than commercial-oriented durable goods manufacturing industries. (Here, we have not made the distinction between A&E and MECH.) The aircraft, aircraft engines, and aircraft parts industries -- which are all grouped in the mixed output sector -- are among the most machine intensive of all manufacturing industries. Unfortunately, the ***American Machinist*** data do not allow us to compare the level of mechanization and composition of the machine inventory of defense- and commercial-oriented establishments in these industries. If this data were available, our analysis would lead us to expect significantly higher levels of machine intensity in commercial aircraft plants.

The ***American Machinist*** database may not be fully compatible with the Census data presented earlier in this briefing. The machine data is organized around the 1972 SIC system, not the updated 1987 version. As a result, the product and market sectors used here vary somewhat from our original Census sample. Moreover, the machine database incorporates all durable manufacturing industries (i.e. major groups SIC 34 - 38). Finally, it is important to note that the ***American Machinist*** data estimates the number of individual machines, and provides no assessment of the value of these machines.

Machine Intensity



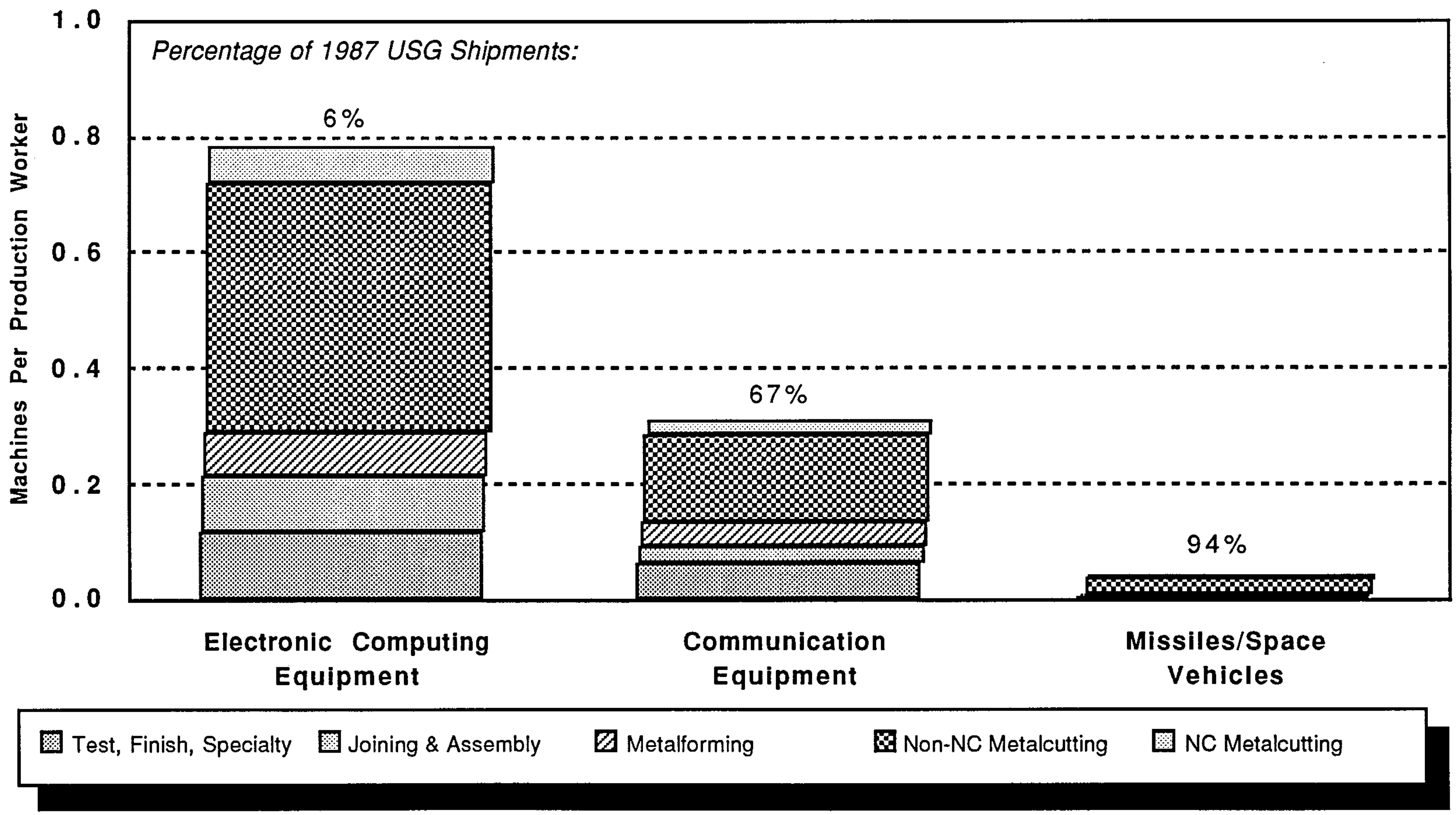
Source: American Machinist, 1989; Bureau of Census, 1987.

Selected Industries -- A&E

This slide highlights the dramatic differences in machine intensity between three key A&E industries -- missiles/space vehicles, communication equipment, and computers. These industries illustrate the general tendency: machine intensity appears inversely related to participation in the defense marketplace. Low production rates characteristic of defense production reduce the cost-effectiveness of automation, while precision orientation increases requirements for highly skilled craftsmen and assemblers.

The divergent levels of mechanization in defense and commercial-oriented industries have important implications for the widespread application of industrial conversion and military-civil integration, which are likely to be most effective when manufacturing requirements of the defense and commercial item are comparable.

Selected Industries -- A&E

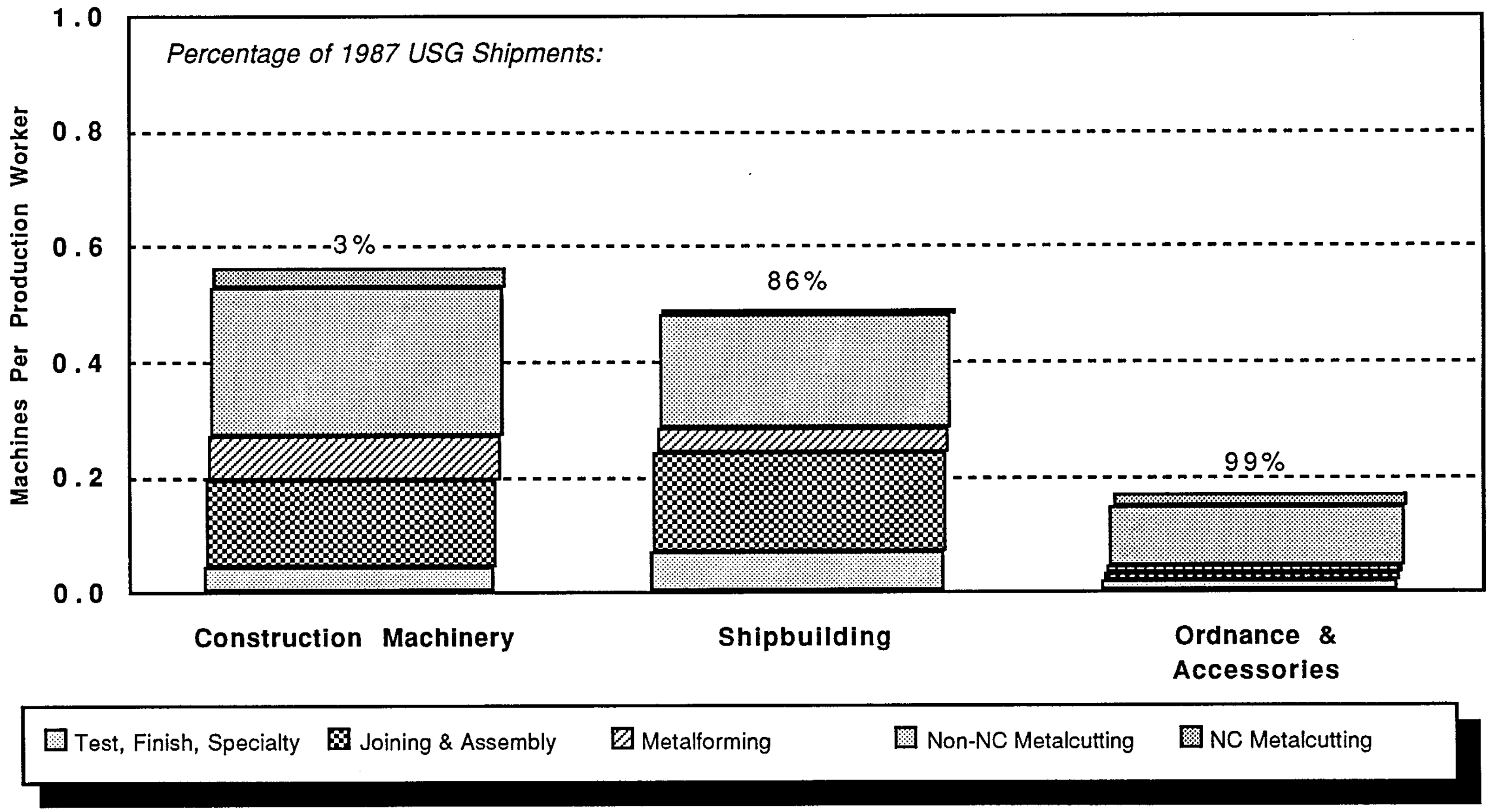


Source: ***American Machinist***, 1989; Bureau of Census, 1987.

Selected Industries -- MECH

The ***American Machinist*** data suggests that production rates and precision orientation also drive machine intensity in the MECH product category. Here, the defense-oriented shipbuilding and ordnance and accessories industries have somewhat lower levels of mechanization than construction machinery. However, MECH industries appear to share one tendency, regardless of market orientation: MECH industries devote more of their machinery to joining and assembly equipment in comparison to their A&E counterparts. This tendency is strongly exhibited in construction machinery and shipbuilding, somewhat less so in ordnance and accessories.

Selected Industries -- MECH



Source: American Machinist, 1989; Bureau of Census, 1987.

Machine Vintage

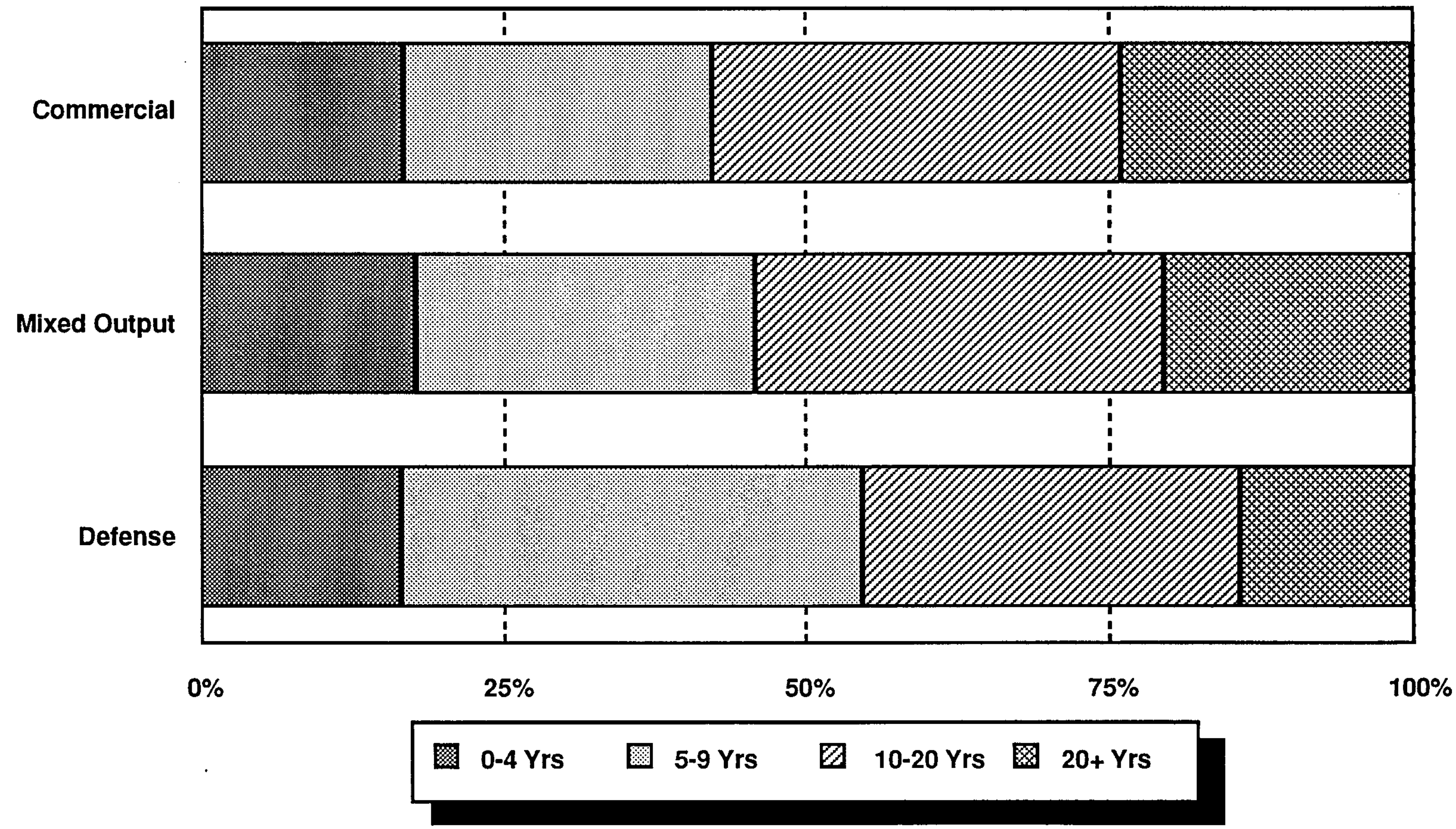
Here, we utilize the ***American Machinist*** database to compare the age of the machine inventory for the defense-oriented, mixed output, and commercial-oriented sectors. The data suggests that, on average, manufacturing equipment in the defense industry is somewhat more modern than in other sectors (or at least this was the case in 1989, when the survey was conducted.)

According to the data, approximately 55 percent of the manufacturing equipment in the defense sector is less than ten years old. For the mixed output and commercial sectors, this figure is only about 45 and 40 percent, respectively. Significantly, approximately 40 percent of the defense sector machine inventory is five to nine years old, a much higher proportion than found in the other sectors.

As the survey was conducted in 1989, machines of this vintage were acquired during the 1980-84 period -- the key years of the Reagan defense build-up. The data suggests that the Reagan build-up stimulated a vast modernization of the defense industry. However, purchases of new manufacturing equipment fell sharply in the 1985-89 period with the deteriorating outlook for the defense market.

The machine data also indicates that the defense sector holds onto significantly fewer older machines. Only some 15 percent of all machines in the defense sector are 20 years old or more.

Machine Vintage



Source: American Machinist, 1989; Bureau of Census, 1987.

Characterization Of The Defense And Commercial Sectors -- Comparative Assessment Findings

This section discuses tentative findings of our comparative analysis of the defense and commercial sectors.

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- **Introduction**
- **Characterization of Defense and Commercial Sectors**
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  - -- Workforce Composition And Costs
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  - -- **Comparative Assessment Findings**
- **Federal Agency Databases**
- **Annex I: Defense Procurement/Industry Cost Translator (DEPICT)**
- **Annex II: Conversion of Industry (COIN) Model**

Comparative Assessment Findings

Comparative Assessment Findings

Industry Cost Distribution

- As a percentage of industry costs, value-added tends to increase with participation in the defense market
- As a percentage of industry costs, payroll costs tend to increase with participation in the defense market
- Payroll accounts for 30-35% of total industry costs in the defense sector
  - -- Defense MECH: 22% production; 12% non-production
  - -- Defense A&E: 10% production; 20% non-production
- In MECH industries (regardless of market orientation), production worker wages average about two thirds of total payroll costs
- In A&E industries (regardless of market orientation), non-production worker wages average about two thirds of total payroll costs
- Product technology (i.e. A&E and MECH) has a stronger impact on industry cost structure than market orientation

Comparative Assessment Findings (Continued...)

Comparative Assessment Findings (Continued...)

Workforce Composition

- Defense industries employ a high proportion of engineers/technicians (about 30% in defense A&E) and relatively few production workers
- The defense production workforce is concentrated in high skill occupations (precision crafts, trades, assembly, etc.)
- Volume-oriented workers (e.g. machine operators and automated assemblers) dominate in the commercial production workforce
- Production support workers (e.g. inspectors, guards, and mechanics) account for a relatively large share of blue collar workers in defense
- Defense industries employ the same proportion of accountants as their commercial counterparts -- only 1-2% of the total workforce
- BLS data indicate that engineers/technicians have much higher administrative support requirements than production workers:
  - -- 76 administrative support workers per 100 engineers/technicians
  - -- 22 administrative support workers per 100 production workers

Comparative Assessment Findings (Continued...)

Comparative Assessment Findings (Continued...)

Workforce Composition (Continued...)

- Large administrative staffs in defense industries appear to be the result of the engineering orientation of defense production, not the DoD acquisition environment
- In contrast, the acquisition environment may greatly increase engineering requirements in defense-oriented industries
- USD(A) should conduct activity-based case studies of defense engineering to assess the impact of DoD acquisition requirements

Compensation

- Defense sector employees receive approximately 10% higher pay on average than their commercial sector counterparts
- Production worker wages account for most of this difference -- a result of the high skill orientation of defense workforce
- Fringe benefits account for a comparable share of total compensation for both defense and non-defense employees (about 20%)

Comparative Assessment Findings (Continued...)

Comparative Assessment Findings (Continued...)

Industry Structure And Manufacturing Processes

- Plants in the defense sector are, on average, much larger than their commercial counterparts
- While the defense sector has less machinery and equipment, its inventory is more modern
- In general, the defense sector leads in the introduction of advanced manufacturing technologies

Federal Agency Data Sources

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Advantages of Federal Agency Data Sources

In the course of conducting this comparative assessment of the defense and commercial sectors, we also sought to establish the usefulness of Federal agency data for industrial analysis. Federal agencies which publish relevant data include (but are not limited to) the Bureau of the Census, the Bureau of Labor Statistics, the Department of Commerce, the National Science Foundation, and the Internal Revenue Service. In our view, DoD has not taken full advantage of these and other potentially useful data sources.

Federal data offer important advantages to DoD. Published Federal agency data are available without charge, and many agencies are willing to undertake special surveys for a modest fee. Moreover, the quality of Federal data is high. Federal data collection agencies employ highly trained specialists with extensive expertise in survey techniques. Finally, Federal agencies use large sample populations and, because of their legal authorities, have excellent response rates. The data are produced at regular intervals and are highly comparable through time and across industry sectors.

A major criticism of Census and other Federal agency data is that the data are too aggregated to be really useful for industrial base analysis. Our response to this concern is twofold: 1) if used appropriately, industry-level data are instrumental for understanding and identifying broad industry or sector trends; and 2) in addition to broad industry statistics, Census publishes detailed product data at the 7-digit SIC level in its ***Current Industrial Reports (CIRs)*** that provide excellent visibility into lower tier suppliers. A more extensive discussion of the CIR data follows below.

During our investigation into Federal agency data sources, agency personnel repeatedly emphasized their willingness to tailor their data collection efforts to further enhance the usefulness of their data for DoD industrial base analysis. For example, through the early 1980s, NSF monitored the differences in the amount of time devoted to administrative tasks for engineers working on military and commercial projects. Such data would be extremely useful for determining the impact of the acquisition environment on engineering requirements. However, NSF eliminated this portion of their engineering surveys some years ago because "no one ever told us they were interested" in the data. NSF officials indicate that they would consider reinstating this portion of the survey, should DoD make such a request.

Greater DoD use of Federal data potentially may also reduce the Department's requirements for special industry surveys and studies -- an important consideration in this era of constrained resources.

For these reasons, we believe that increased reliance on Federal data, if used to complement ongoing DoD data collection efforts, would greatly enhance DoD's ability to identify -- and respond to -- industrial base developments.

Advantages of Federal Agency Data Sources

- Low Cost
- Quality of Data
- Includes Suppliers
- Product-Level Visibility
- Willingness to Tailor Data Collection
- Could Reduce Industry Reporting Requirements

DoD should view Federal agency databases as a cost effective source of information for industrial base planning and analysis.

CIR Product-Level Data

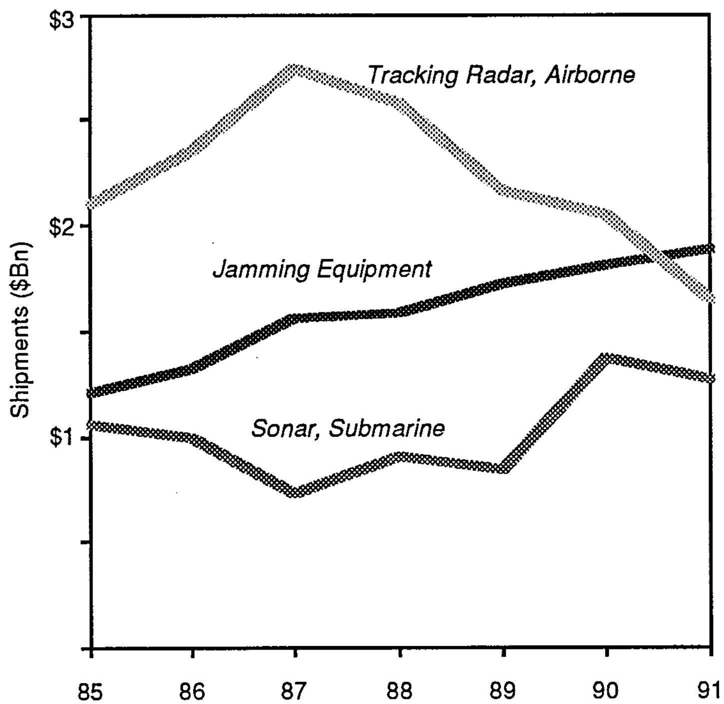
As noted above, ***Current Industrial Reports*** **(CIRs)** provide important visibility into lower tier industry trends. CIRs are annual publications that contain information on the number of companies participating in specific product markets; the quantity and volume of product shipments; export and import statistics; and (in some cases) backlog and order information at the detailed 7-digit SIC level. As far as we know, no OSD office uses this data in a systematic fashion to analyze the defense industrial base.

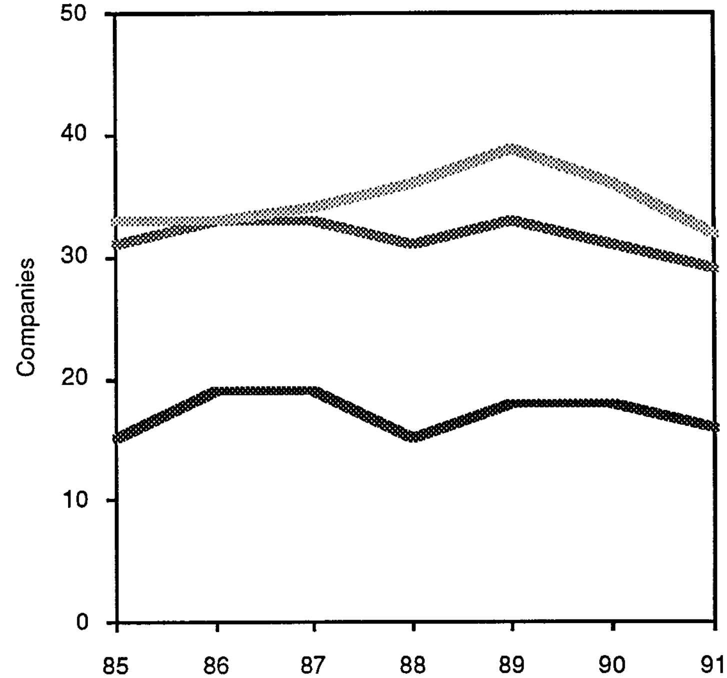
This slide illustrates the potential utility of the CIR data. It provides historical data on the value of shipments and company participation for three defense-related product classes: airborne tracking radar, submarine-based sonar equipment, and jamming equipment. The data indicate that shipments of airborne tracking radars declined from about $2.7 billion to $1.7 billion in the 1987-91 period. There has been a corresponding decline in the number of companies involved in the production of this radar equipment. In contrast, shipments of jamming equipment increased steadily in the 1985-91 period; production of jamming equipment has remained concentrated in comparatively few firms.

This data would be particularly useful to DoD industrial base planners if it were possible to identify each of the firms that participates in specific product markets. According to Census officials, such company-specific information may be released if the relevant survey is conducted under the authority of the Defense Production Act. Currently, most CIR surveys are performed under the legal authority of the Bureau of Census, which forbids the release of company-specific information to private parties or other Federal agencies. However, Census officials have indicated a willingness to take necessary measures to ensure that appropriate company-specific data are made available to DoD.

Census is also taking action to improve the accessibility and timeliness of the CIR data -- longstanding sources of concern among data users. In 1993, for the first time, Census will make CIR data available via an electronic bulletin board. This innovation will move up publication several months, making possible the release of 1992 data in the June-July 1993 time frame. Moreover, Census officials have expressed a willingness to consider release of preliminary estimates in the April-May period.

CIR Product-Level Data





Census data provides useful visibility into lower tier suppliers.

Source: Current Industrial Reports: MA38B, Bureau of the Census.

Recommendations Regarding Federal Agency Data Sources

We believe DoD should undertake a systematic effort to consolidate, collect, and distribute relevant Federal agency data. There should be one office in OSD with the primary responsibility for identifying relevant databases and for making this information available to the appropriate analysis and policy makers.

The 1992 reauthorization of the Defense Production Act instructs DoD to work closely with the Bureau of the Census to improve the usefulness of Census industry statistics for defense industrial base planning and analysis. DoD should convene an interagency working group to identify and tailor all relevant databases. Working group members should include (among others) OSD, the Military Services, FEMA, Census, BLS, Commerce, IRS, and NSF.

The BLS industry occupation database would present an excellent target of opportunity for such an interagency group. While BLS conducts its surveys at the establishment (or 4-digit SIC) level, the data is published only at the industry group (or 3-digit SIC) level. With the more detailed data, DoD could more easily identify critical skills in the defense workforce and better understand the allocation of costs within specific defense-oriented industries. Preliminary discussions with BLS indicate that the agency would consider making available the detailed data, but would require limited funding to support the development of the necessary computer program.

Finally, we believe the Defense Economic Impact Modeling System (DEIMS) translator should be updated and revised. (The limitations of the translator, which was last revised in the mid-1980s, are discussed in Annex I.) While DEIMS was designed primarily as a macroeconomic tool, the translator can be used in tandem with Census and other Federal agency data to better understand the allocation of costs in the defense industry.

In Annex I and Annex II, we describe and demonstrate two interactive industrial base tools that utilize Federal agency data. Our DEPICT and COIN tools should be viewed as illustrative examples of the potential utility of Federal data for industrial base analysis. However, with further development, we believe these models could be used in a range of applications for industrial base planning and analysis.

Recommendations Regarding Federal Agency Data Sources

- OSD should designate a single office with primary responsibility for coordinating, collecting, and distributing Federal agency data within DoD
- OSD should work closely with other Federal agencies to enhance the usefulness of this data for DoD
- OSD should encourage BLS to make available its industry/occupation databases at the 4-digit SIC level
- Federal data should be incorporated into the Defense Industrial Base Information System to be established under the Defense Production Act
- The DEIMS translator should be updated to accurately reflect the full contributions of lower tier suppliers

Annex I: Defense Procurement/Industry Cost Translator (DEPICT)

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DEPICT Overview

DEPICT provides a real time, interactive medium for consolidating much of the analysis presented in previous sections of this briefing. This tool allocates DoD appropriations to detailed industry cost categories; allows comparative assessment of acquisition categories, industry sectors, and tiers; and provides a prototype "what-if" capability to estimate the cost impact of various scenarios. With the incorporation of historical data, DEPICT has the capability to track trends in the composition of industry costs over time.

In essence, DEPICT represents a systematic effort to integrate key Federal agency databases. The Census of Manufactures provides a general framework for industry costs with its data on total shipments, value added, payroll, capital expenditures, etc. With the BLS industry occupation database and wage survey information, we can further desegregate payroll costs by occupation category. The input/output table provides added detail for our NPVA cost categories. When consolidated, these data sources provide a detailed cost breakdown at the industry level. Finally, we used the input/output table and the translator embedded in DoD's Defense Economic Impact Modeling System (DEIMS) -- which converts defense appropriations into industry shipments -- to develop a stylized model representing the tier structure for each major procurement category (military aircraft, shipbuilding, armored vehicles, missiles & space systems, communications, and ordnance).

In its current form, DEPICT is intended to be primarily a presentation tool that illustrates the possible applications of this approach; various data limitations limit its usefulness at this time for formal industrial base analysis. These limitations include: the difference in the levels of aggregation in the BLS occupation data (provided at the three digit SIC level) and in the Census of Manufactures industry statistics (provided at the four and five digit SIC level); the lack of comprehensive wage information on an industry and/or occupation basis; and the stylized representation of the lower tier suppliers. We believe, however, that with moderate effort many of these limitations may be overcome, and the DEPICT has the potential to serve as the basis for a cost-effective, top-level approach for monitoring and analysis of cost trends in the defense industry.

DEPICT Overview

Capabilities

- Allocates DoD appropriations to industry cost categories
- Allows comparative assessment of procurement categories, industry sectors, and tiers
- Provides prototype "what-if" capability to estimate cost impacts

Structure

- Integration of Census, BLS data yield detailed industry structure
- DEIMS translator and I/O table distribute appropriations
- Sylized representation of lower tier suppliers

Three Perspectives

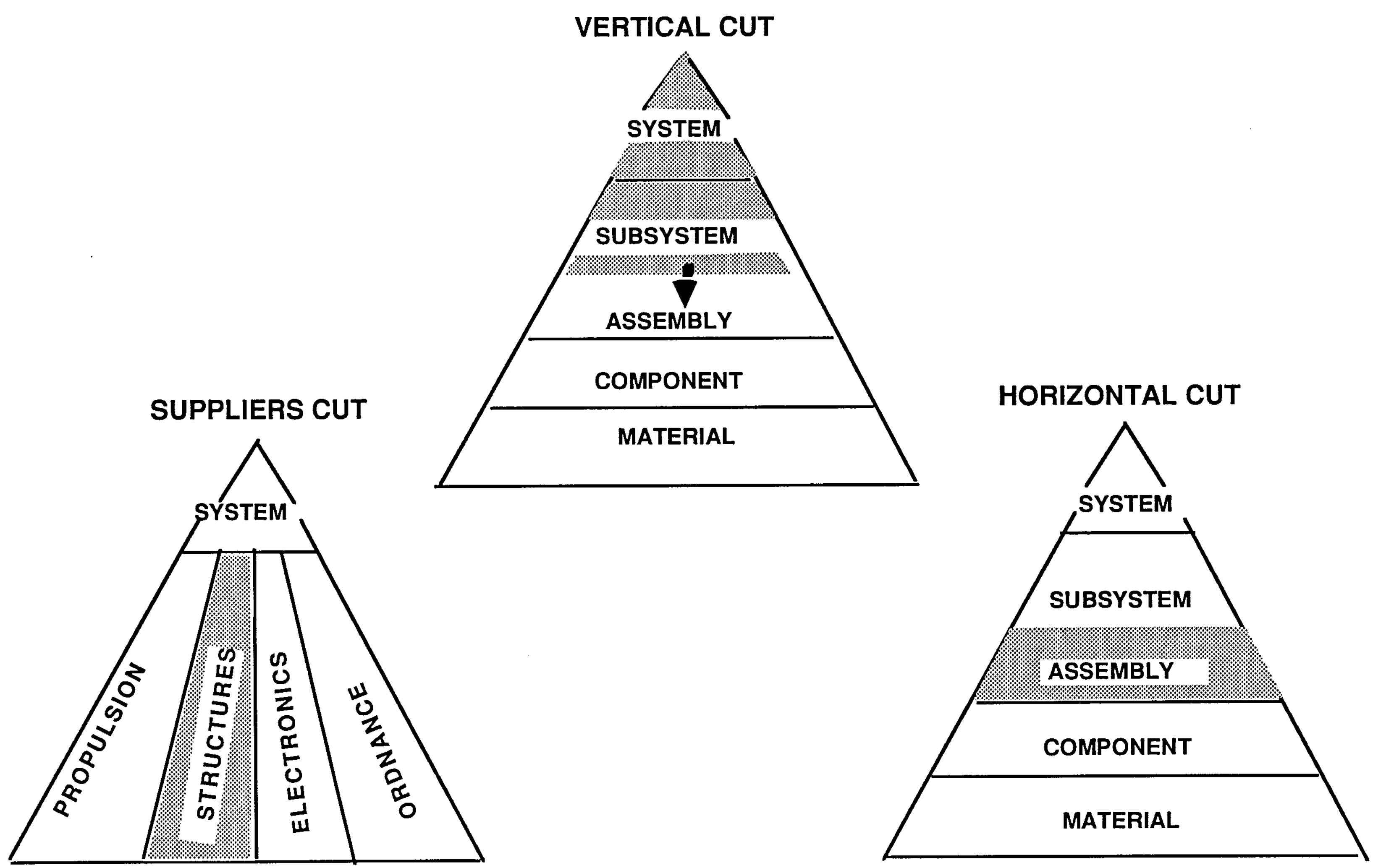
DEPICT provides three different perspectives on industry costs for each of the major procurement categories (with the exception of combat support) in a real time, interactive environment.

The "vertical cut" tracks the accumulation of industry costs as one moves from the prime contractor level down through the industry tier structure. Thus, at the system level, the vertical cut perspective indicates the composition of industry costs for the prime contractors within a given procurement category. At the subsystem level, DEPICT cumulates both prime contractor and major subcontractor costs. The vertical cut permits this cumulation to continue down to the material suppliers.

With the "horizontal cut," DEPICT estimates the cost composition and value added contribution of any specified horizontal tier. The horizontal perspective would allow users to estimate, for example, component costs as a percentage of total system costs within a given procurement category.

Finally, the "suppliers cut" provides insight into the cost composition and value added contribution of the four major supplying industries -- propulsion, structures, electronics/avionics, and ordnance -- for each of the major procurement categories .

Three Perspectives



DEPICT Sample Output

This slide provides a sample DEPICT output screen for the military aircraft category. The quadrant entitled "DEPICT -- MILAIR" in the lower right corner is the control panel. The "Slice" (small font) and "V/H Tier" entries are input boxes that allow the user to select the desired vertical, horizontal, or supplier perspective. The "Value Added" box indicates the total value added of the designated tiers for $100 in defense appropriations. The tiers or sectors represented are indicated at the top of the control panel in the "Slice" (large font) box. On the right side of the control panel, there are several variables that may be manipulated by the user to conduct "what-if" analysis (production worker wages, etc.). Finally, at the bottom of the control panel, the "Savings" box calculates the projected cost impact of the hypothetical case.

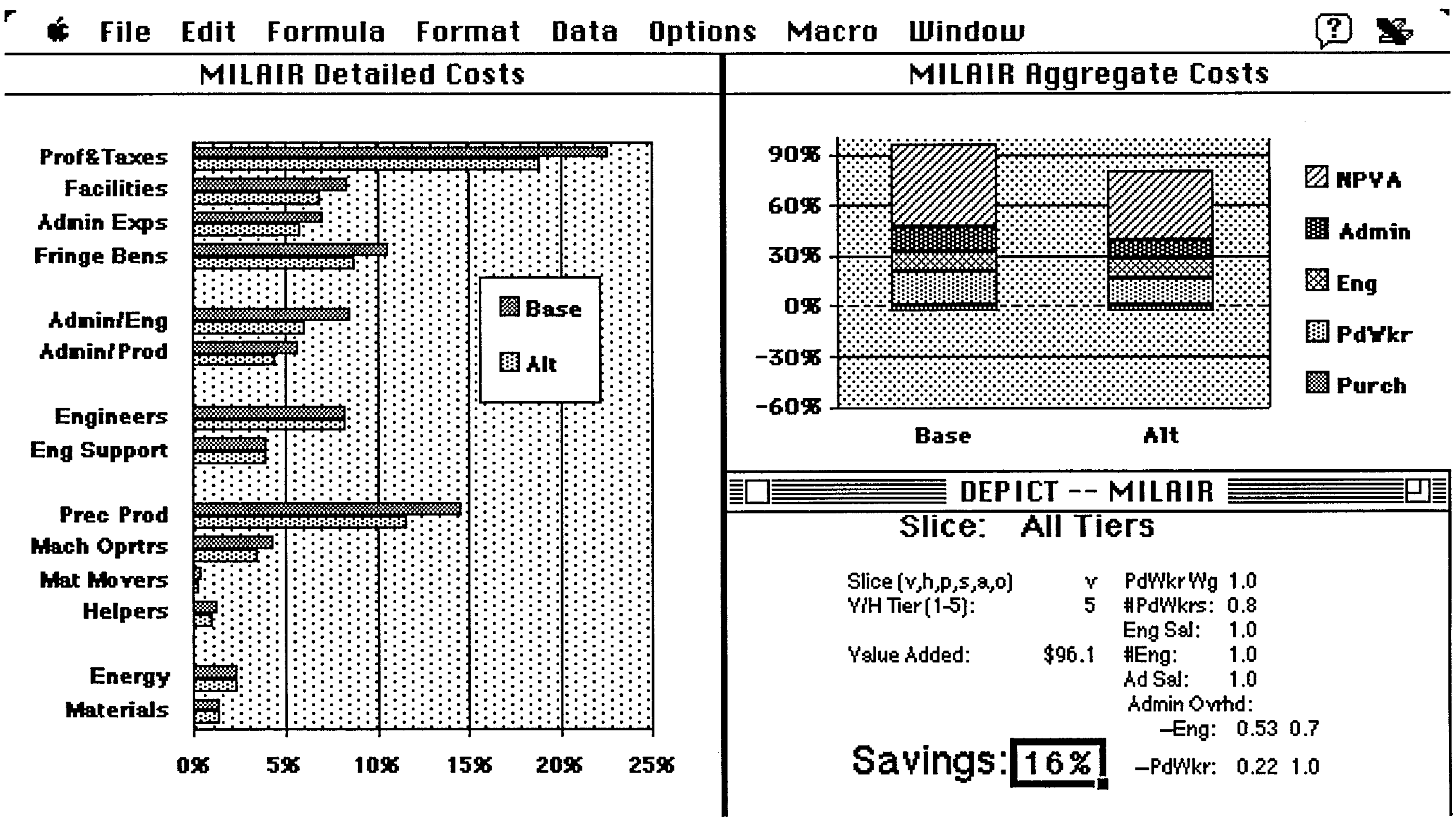
In this example, the user has chosen the vertical perspective through the fifth tier (the material suppliers). Accordingly, the control panel indicates that DEPICT output represents "All Tiers." For the military aircraft category, tiers 1-5 account for $96.1 out of every $100 of defense appropriations. The user has selected a hypothetical case in which production worker wages are reduced by 20 percent and the administrative manpower support requirement of engineers and technicians is lowered by 30 percent. This "what if" hypothetical would result in projected industry savings of 16 percent.

The "MILAIR Aggregate Costs" quadrant in the upper right provides a cost composition summary for both the base and alternative cases. This summary uses the familiar industry cost framework employed throughout this briefing. This base case summary column indicates that, when one takes into consideration the entire tier structure, NPVA costs account for almost half of total industry costs in the military aircraft procurement category.

The right side of the DEPICT screen breaks down aggregate industry costs into 14 detailed cost categories for both the base and hypothetical cases. "NPVA" disaggregates into the "Prof&Tax," "Facilities," "Admin Exps," and "Fringe Bens" categories. The "Admin" category is separated into "Admin/Eng" (administrative personnel supporting engineering) and "Admin/Prod" (administrative personnel supporting production). "Eng" is broken down into "Engineers" and "Eng Support." "PdWkrs" are disaggregated into "Prec Prod" (precision crafts and assemblers), "Mach Oprtrs" (fabricators/assemblers using machines to conduct repetitive tasks), "Mat Movers," and "Helpers." "Purch" (purchases) are separated into "Energy" and Materials." While the number of categories is limited by the capacity of the computer screen -- not the data -- we believe the detailed cost breakdown presented here provides valuable insights into the composition of industry costs.

It is important to note that the "Prof&Tax" category includes interest payments and other financial charges in addition to profits and taxes.

DEPICT Sample Output



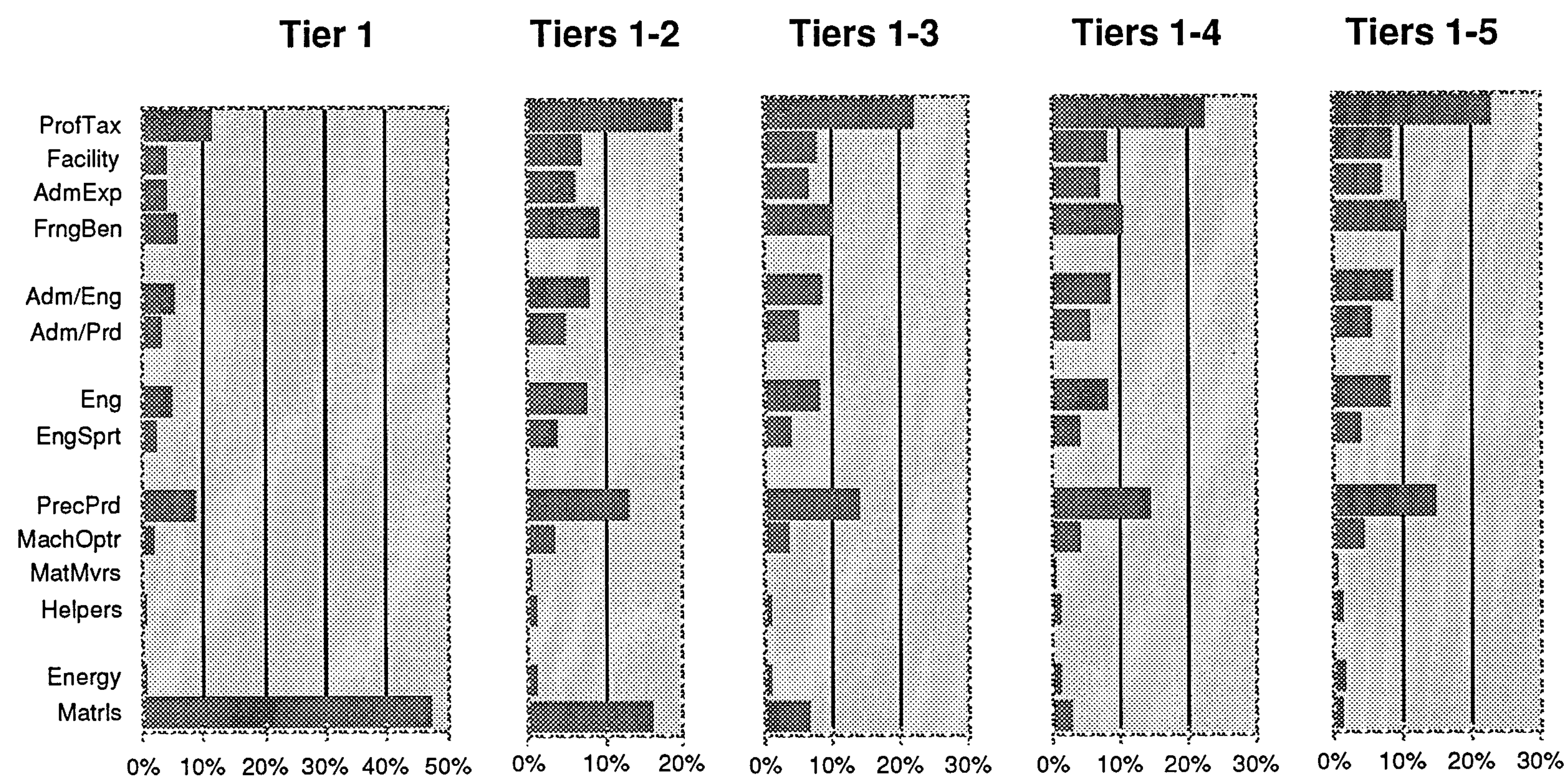
Vertical Cut, Military Aircraft

This slide summarizes the DEPICT vertical perspective for the military aircraft procurement category. As DEPICT moves down through the tier structure, industry expenditures devoted to the purchase of materials (at the bottom of the slide) diminish. In turn, costs associated with other categories accumulate. At the prime level, material purchases account for 48 percent of industry costs; when Tiers 1-5 are considered, materials account for only about two percent of total expenditures.

Several noteworthy insights may be drawn from this summary slide including, for example, the relative importance and composition of production worker wages. At the prime contractor level, production worker wages total about 11 percent of total costs, and are concentrated in the precision fabrication and assembly area. Prime contractors in the military aircraft sector may be characterized primarily as system designers and system integrators with limited production-oriented resources and capabilities.

When considering the entire tier structure, production worker wages still total only about 20 percent of total costs. This figure is dwarfed by the NPVA categories for tiers 1-5, which together account for almost half of all costs. Thus, when DoD appropriates $100 for military aircraft, about $50 are consumed by overhead as defined by NPVA.

Vertical Cut, Military Aircraft



Value Added Per $100 Appro: $52.0 | $83.1 | $92.1 | $95.7 | $96.9

Horizontal Cut, Ships

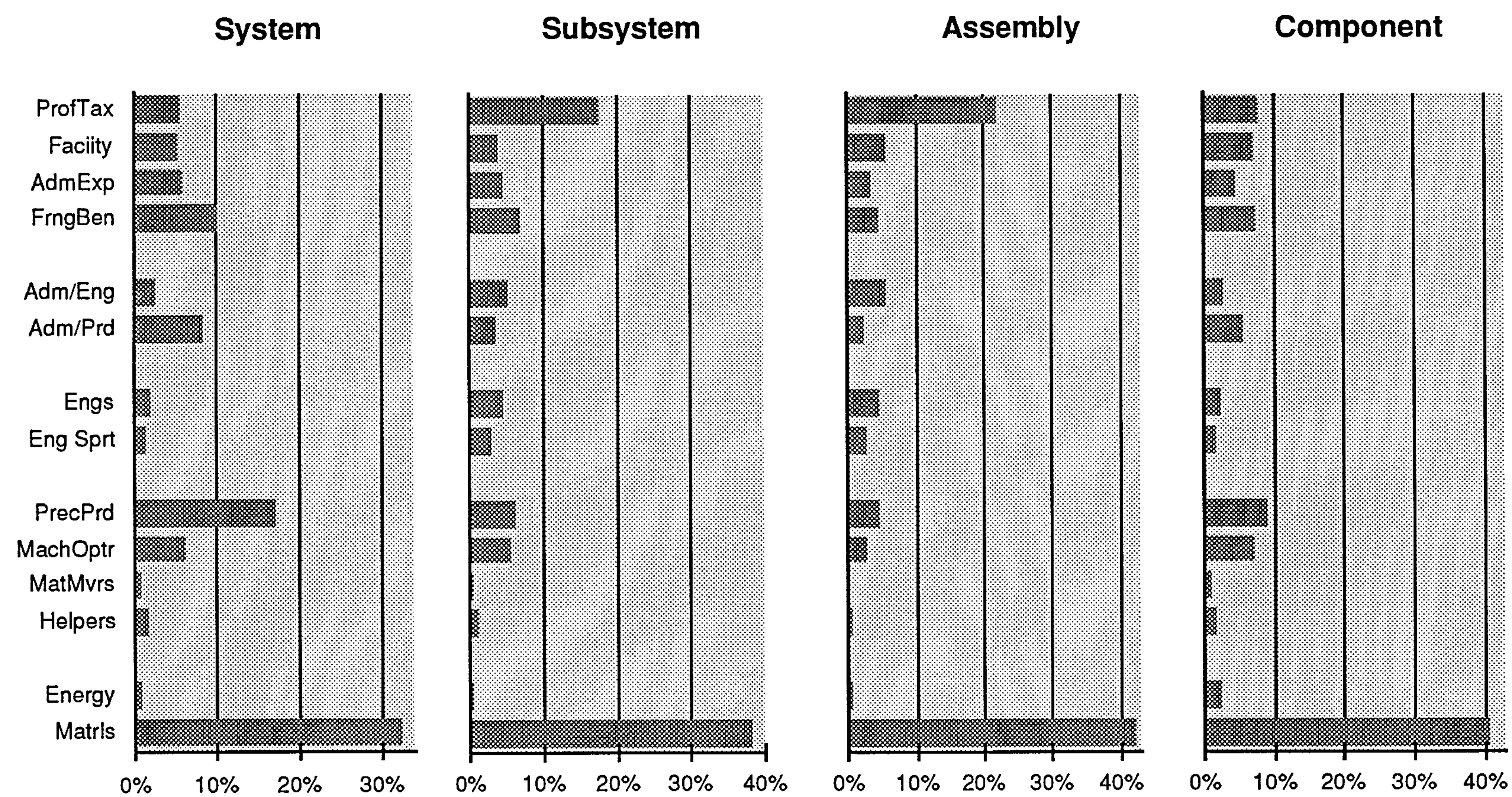
This slide summarizes the DEPICT horizontal perspective for naval ships. This perspective allows the user to compare the differences in cost composition and value added across tiers. For each tier, the sum of the individual cost categories equals 100 percent.

In the naval ship procurement category, production worker wages account for a relatively large portion of total costs at the system level -- about 25 percent. Production costs are strongly concentrated in the precision craft and assembly area (i.e. shipfitters, pipefitters, and welders). For other tiers, production labor accounts for a smaller percentage of total costs, and production worker wages are more balanced between the precision occupations and less highly skilled production functions.

It is also interesting to note that energy becomes a significant cost category for lower tier suppliers. At the materials level, energy costs represent about 12 percent of total industry expenditures.

Finally, the value added figures indicate that system and major subsystem tier levels account for the lion's share of industry value added ($67.1 and $21.3, respectively, of $100 in defense appropriations) in the naval ship procurement category. While lower tier suppliers may provide items that are critical to the performance of the system, they are not major cost contributors. This analysis suggests that cost reduction efforts should be focused primarily at the first and second tier.

Horizontal Cut, Ships

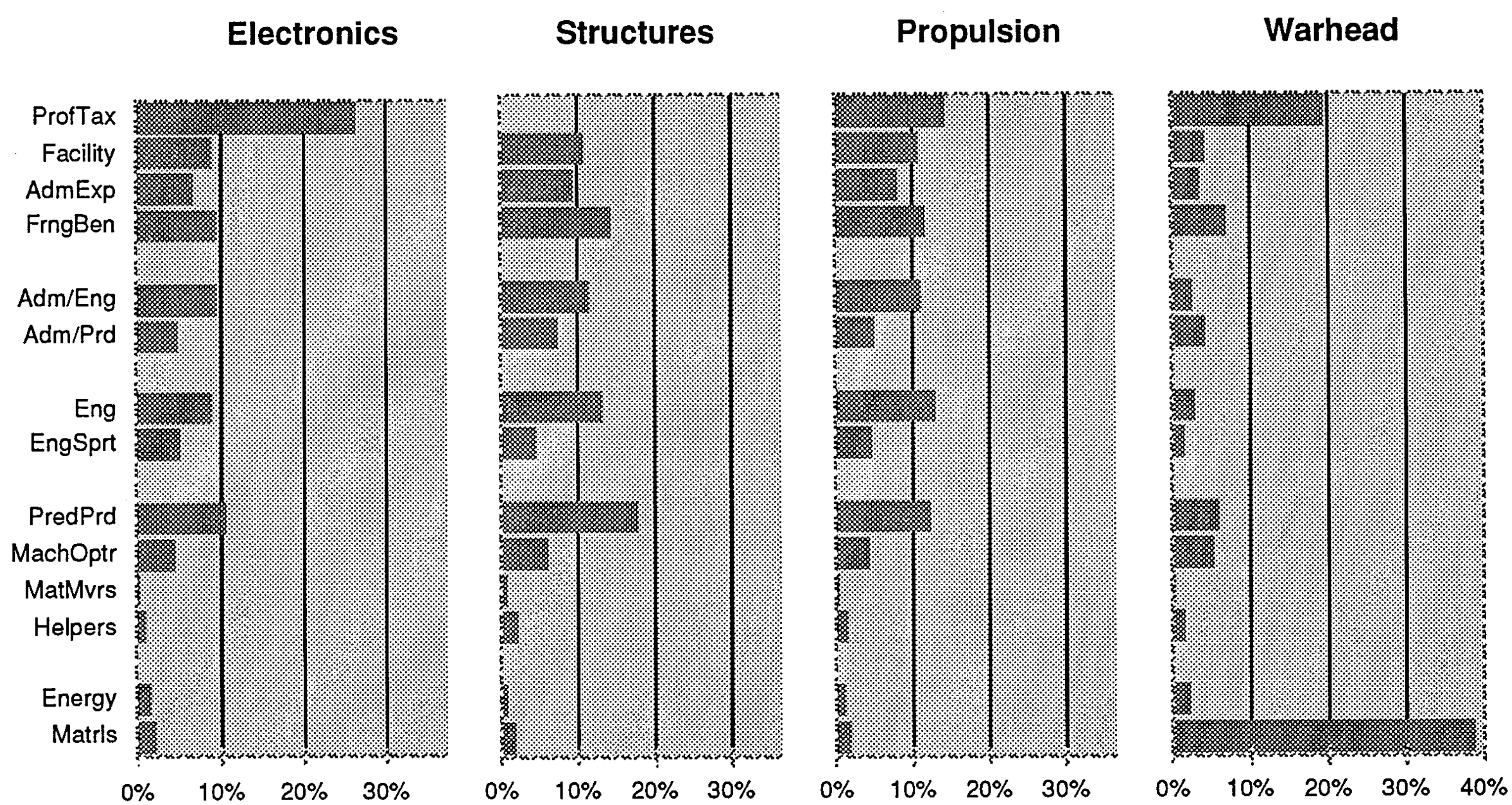


Value Added
Per $100 Appro: $67.1 $21.3 $2.4 $2.6

Suppliers Cut, Missiles

This suppliers cut for the missile procurement category provides the cost composition and value added contribution of the major industry groupings supplying the prime contractors. The electronic sector accounts for $26.5 of $100 in defense appropriations, by far the largest contribution of the supplying sectors. It is important to note that this estimate reflects the value of components and other materials purchased from electronic suppliers, not the total value of electronics in the missile acquisitions. Electronic devices and assemblies produced in-house are included in the value added contribution of the prime contractor.

Suppliers Cut, Missiles



Value Added Per $100 Appro:	**$26.5**	**$2.2**	**$2.9**	**$4.4**

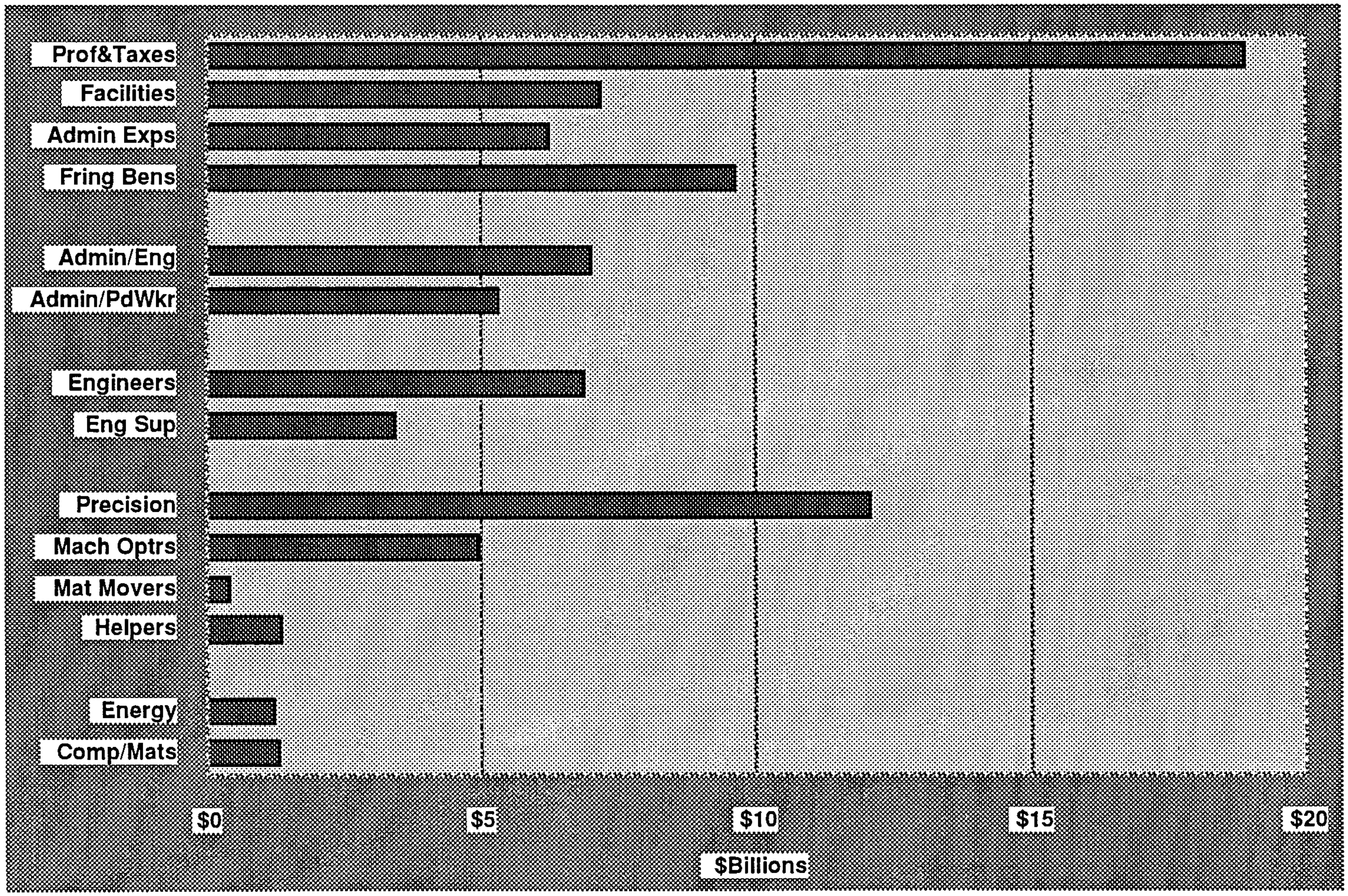
FY90 Appropriations

Here, we consolidate industry costs of tiers 1-5 for each of the major procurement categories into a single summary slide (combat support is excluded) and convert percentages into FY90 defense appropriations dollars (RDT&E and procurement). During FY90, appropriations for these procurement categories totaled $88 billion.

The single most important cost area is the profit and taxes category, which as noted also includes finance charges and other transaction costs. This category accounts for $19 billion, or about 22 percent of defense appropriations/industry costs. (The large size of this cost category probably reflects the "pyramiding" of profits from lower tier suppliers.) Fringe benefits are also a very significant NPVA expense at about $10 billion.

Production worker payroll costs, including the salaries of administrative personnel supporting the production process, total about $25 billion or 28 percent of defense appropriations/industry costs. Wages for precision workers (skilled crafts, trades, and precision assembly) total about $12 billion. In contrast, salaries for engineers, technicians, and related personnel (including administrative workers supporting the engineering function) represent about $19 billion, about 22 percent of the total.

FY90 Appropriations



Note: excludes combat support.

Appropriations, Suppliers Cut

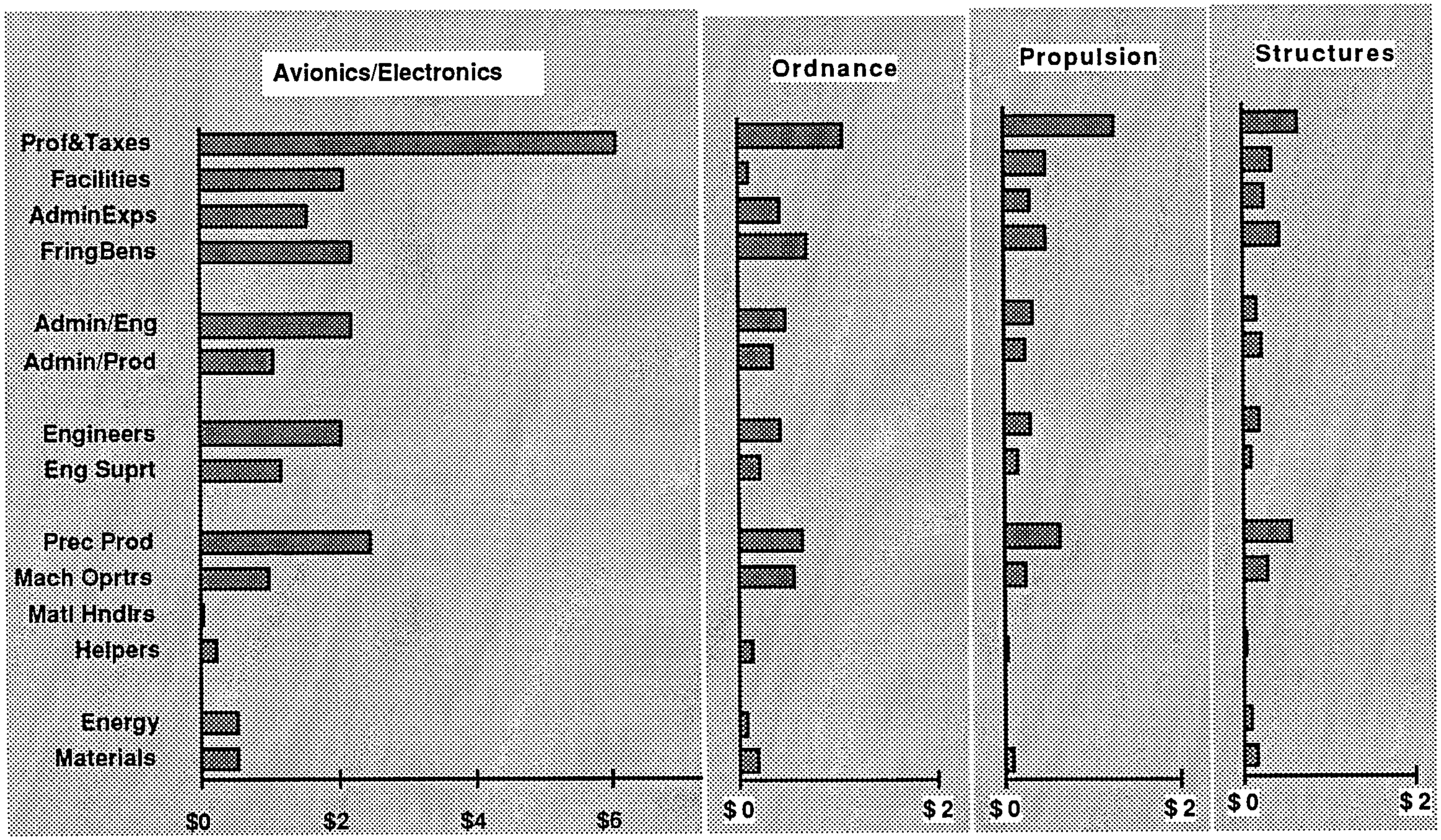
This appropriations summary for the DEPICT suppliers perspective indicates that the avionics/electronics sector is, by a considerable margin, the major supplying sector with $26.5 per $100 in 1990 defense appropriations -- more than the other supplying industry sectors combined. As noted above, DEPICT relies on the translator from PA&E's DEIMS model to establish the relationship between prime contractor and supplier industries.

While in general we have confidence in the DEIMS translator, this slide raises questions regarding its accuracy in some important respects. For example, according to the translator, the propulsion sector accounts for $2.9 per $100 in defense appropriations. This figure converts into total defense shipments of approximately $3.3 billion for 1990. However, we have determined that the value of aircraft engines provided to DoD by two major aircraft manufacturers (General Electric and Pratt & Whitney) during this year exceeded this figure slightly -- before adding the DoD shipments of manufacturers of missile, armored vehicle, and marine propulsion systems

We believe that the DEIMS translator, which was last validated in the mid-1980s, should be updated and revised to accurately reflect the contribution of supplier industries in defense production. An updated translator would greatly enhance the usefulness of our approach for assessing allocation of costs in the defense sector.

The translator affects only our estimate of the value added contributed by each industry sector. DIEMS has no bearing on the distribution of costs within specific industries.

Appropriations, Suppliers Cut



Value Added ($Bn): $22.5 $5.4 $4.9 $3.4

Search & Navigation vs. Electronic Computers

In this slide, we use the DEPICT framework to compare the cost composition of a pair of defense- and commercial-oriented A&E industries which have relatively comparable labor skills: search & navigation equipment (SIC 3812) and electronic computers (SIC 3573). Search & navigation equipment is a strongly defense-oriented industry which in 1987 provided 86 percent of total industry shipments to DoD and other Federal agencies. In contrast, the electronic computer industry provided only about 7 percent of its shipments to the Federal government during that same year.

To conduct the most meaningful comparison, we analyzed industry costs on a per employee basis. The slide shows that, while there is rough comparability in the distribution of payroll costs per employee -- a function of the labor force similarity -- there were great disparities in per employee expenditures for both profit, taxes, and finance charges ($17,000 for search & navigation vs. $64,000 for electronic computers) as well as material purchases ($32,000 vs. $100,000).

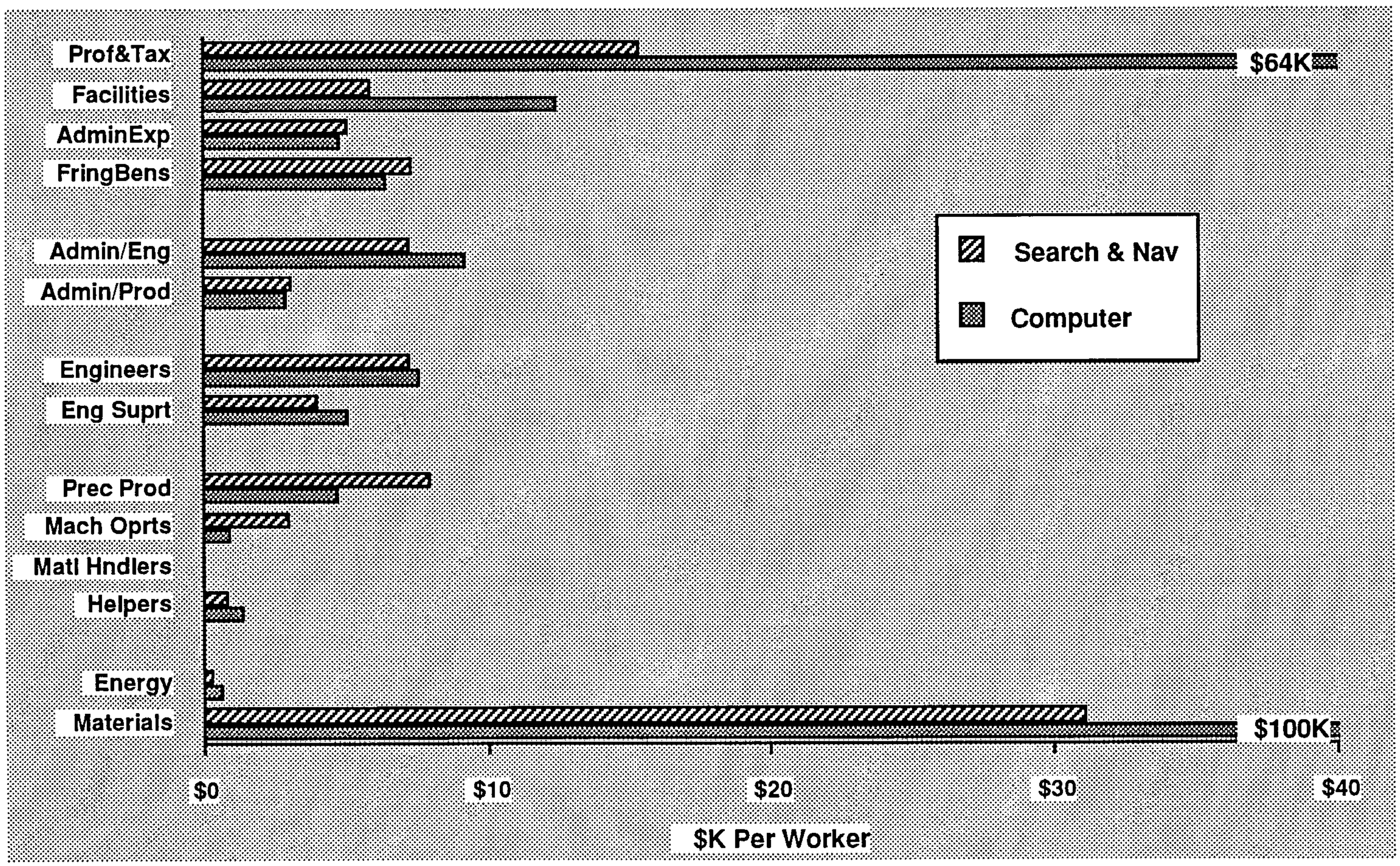
It is also noteworthy that facilities expenditures for electronic computers ($13,000 per employee) were about double the level for search & navigation ($7,000 per employee). These figures are consistent with the American Machinist data, which indicate that there are .8 manufacturing machines per production worker in the computer industry, compared to only about .3 for the search & navigation sector.

These significant disparities appear to indicate fundamental differences in the production process and structure of the two industries. The high level of purchases and facilities expenditures per employee in electronic computers reflects the high production volumes and extensive automation associated with this industry.

The DEPICT framework promotes understanding of the complexity and the unique nature of specific industries. This analysis suggests that it may be difficult for firms or industries to achieve a greater integration of defense and commercial production, even when the workforce requirements are generally comparable.

Search & Navigation vs. Computer

Distribution of Costs Per Employee



Shipbuilding vs. Automobiles

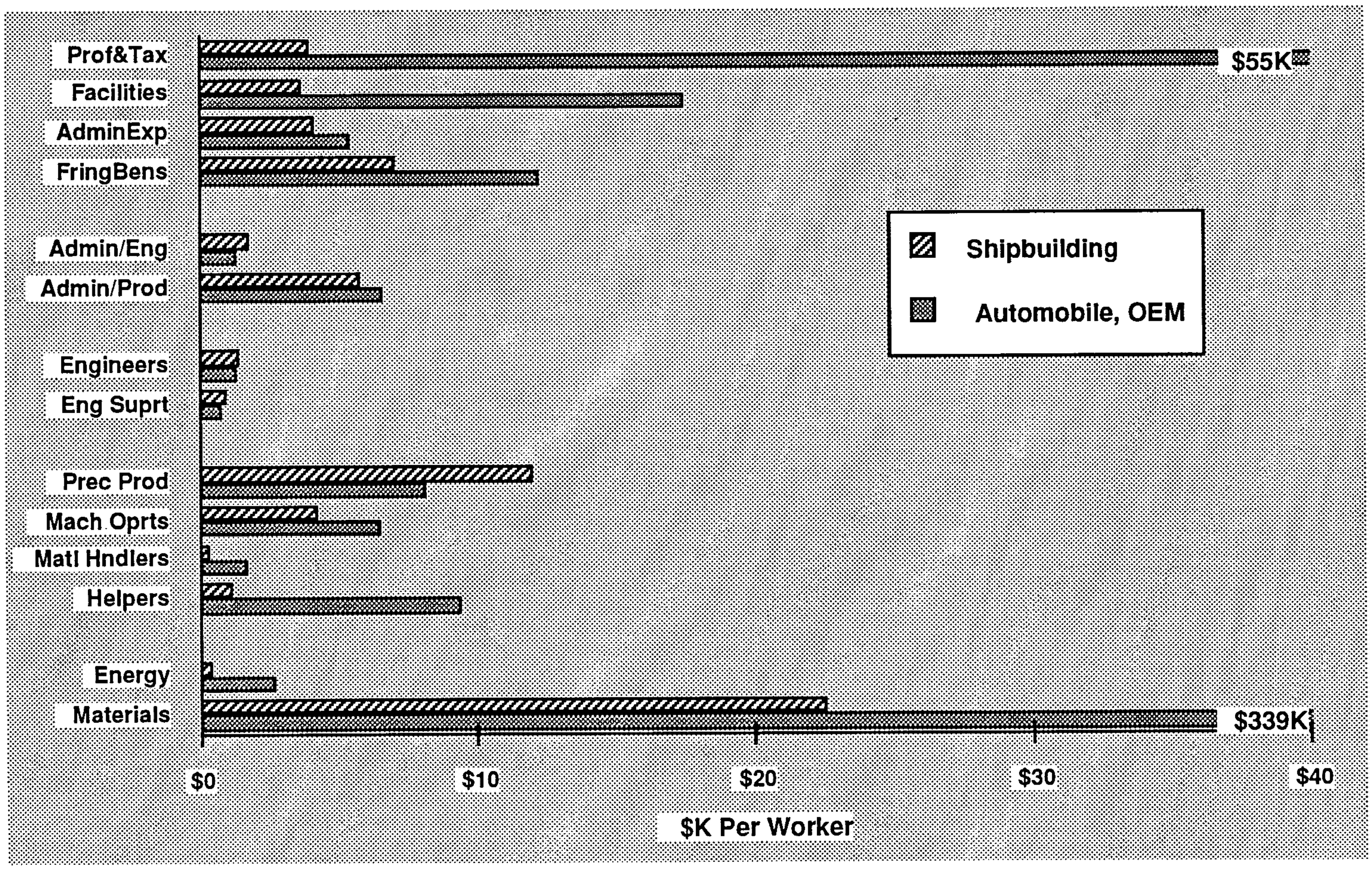
In this slide, we contrast a pair of defense- and commercial-oriented MECH industries -- shipbuilding and automobile assembly. While the workforce composition of the two sectors varies somewhat -- the production workforce in the shipbuilding industry is concentrated in skilled trades, and automobile workers are mostly engaged in less highly skilled assembly operations -- this comparison reveals structural differences driven largely by the differences in production volumes .

In the automobile assembly industry, the high production volumes (reflected in the material purchase level of $339,000 per employee) encourage extensive automation (reflected in $18,000 per employee in facilities costs). Because of the repetitive and relatively automated nature of production, the automobile assembly workforce employs mostly machine operators and low skilled hand workers, and comparatively few high skill, high pay precision workers. These economies result (at least in 1987) in relatively high profits per employee.

Shipbuilding is the archetypal low volume industry. Because production volumes are so small, there are fewer repetitive tasks and little incentive to reduce costs through investment in automation. As a result, facilities costs per employee are anemic (about $4,000 per employee), and the production workforce in concentrated in high skill crafts and trades. While there are probably other factors involved as well, the relatively low productivity of the shipbuilding workforce undoubtably contributes to the poor profit performance of the industry.

Shipbuilding vs. Autos

Distribution of Costs Per Employee



Annex II: Conversion of Industry (COIN) Model

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COIN Overview

The Conversion of Industry (COIN) is a stylized model that demonstrates the interplay of production volumes, performance requirements, and other market factors on unit costs and workforce requirements. To this point, our analysis has been largely resource-based with a focus on workforce composition, wage rates, machine inventories, etc. COIN extends the analysis to examine the impact of resource factors on industry output.

The objective of COIN is to illuminate the fundamental forces that contribute to the great disparity in the costs of defense equipment and most commercial items. To do this, COIN allows the user to manipulate a variety of production factors (volumes, complexity, precision, performance, government regulations, plant utilization, and labor productivity) in order to "convert" a 1000-employee facility that manufactures refrigerators into a 200,000-worker aerospace sector that produces advanced combat aircraft. In the process, output prices increase from $6 per pound for the refrigerator to about $6000 per pound for advanced combat aircraft.

Clearly, there is considerable subjectivity involved in projecting the impact of various production factors on output costs and workforce requirements. However, COIN uses real data for its starting point: the workforce composition and industry cost distribution of the refrigerator plant are taken directly from the Census of Manufactures and BLS occupation data. The end point is also anchored in reality, as $6000 per pound is typical for advanced tactical aircraft. Moreover, the workforce figures for the "converted" aerospace sector are consistent with trends observed in the BLS data.

We have devised algorithms to project the impact of production factors which are consistent with the industry data presented throughout this analysis and with our understanding of the manufacturing process. While COIN has not been fully validated, its assumptions are transparent and modifiable.

COIN Overview

- Allows user to "convert" an appliance factory into a high technology defense industry
- Assesses relative impact of performance, production volume, government requirements, and other factors on industry cost distribution, workforce composition, and unit costs
- Permits assessment of <u>absolute</u> costs in addition to <u>distribution</u> of costs
- While algorithms are consistent with our industry data and understanding of the manufacturing process, COIN has not been validated and remains highly stylized

Cost/Degree of Difficulty Curve

The cost/degree of difficulty curve displayed on this slide illustrates a key concept demonstrated by the COIN model: unit costs increase geometrically as performance approaches the limits of technological feasibility.

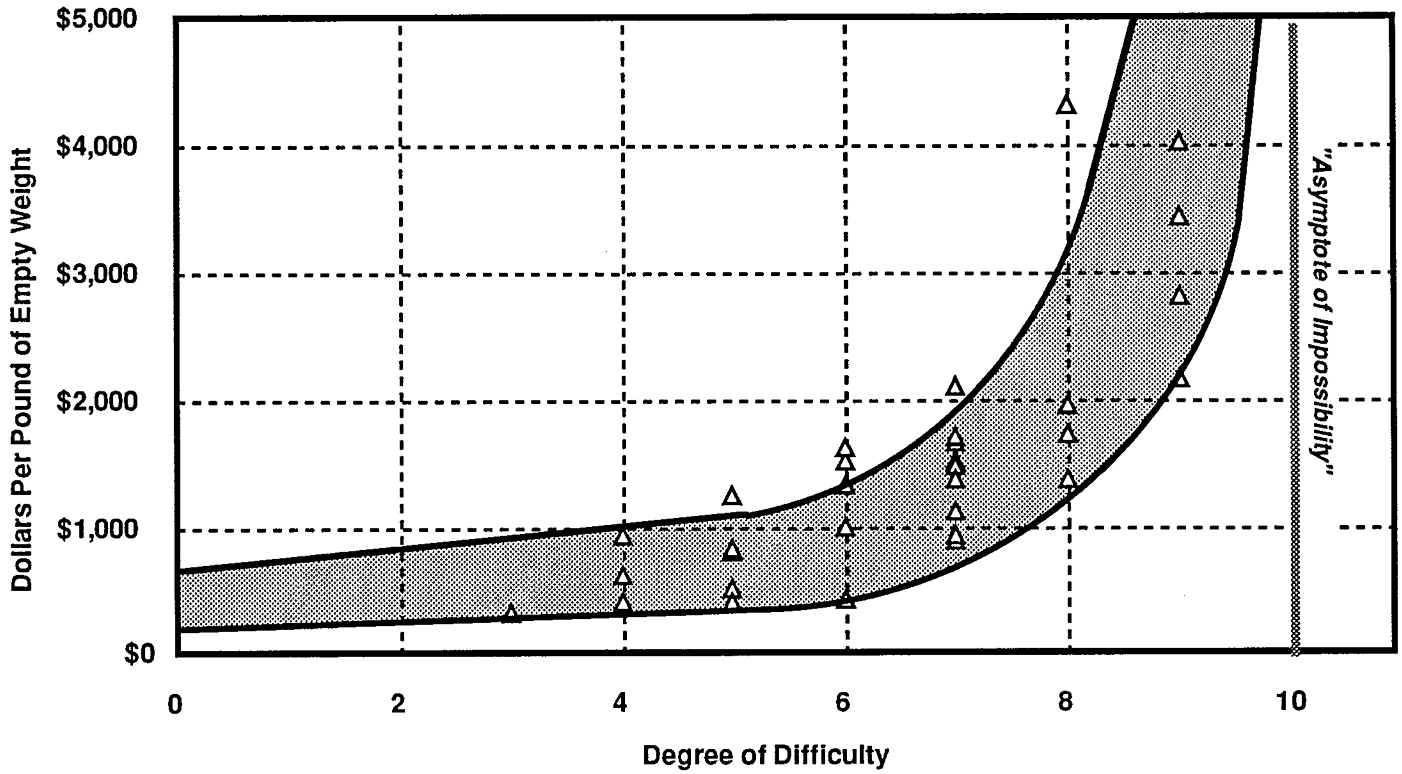
To derive this curve, we began with a sample of 34 aircraft models, both commercial and military, developed and produced from the early 1960s through the late 1980s. Each of these aircraft was assigned a performance score based on four primary attributes: speed, avionics, take-off range/platform, and special features (e.g. variable sweep wings, stealth, etc.). The maximum score of 10 would indicate "perfect" performance. Next, we determined the unit price per pound (empty weight) of each aircraft. All unit prices were taken at the 100th production unit, and expressed in constant 1992 dollars.

Since it was necessary to take into account the impact on unit prices of technological progress, we normalized our sample so that all the aircraft could be treated as if they were introduced in 1994. To accomplish this, we added 5 percent to the unit price per pound for each post-introduction year prior to 1994. (Earlier research has shown that unit prices for aircraft have historically increased at this annual rate, after discounting for inflation.[5]) In other words, since the F-5E was introduced in 1976, we added 5 percent to its unit price 18 times.

The slide summarizes the results of this analysis. At lower levels of performance, unit prices increase relatively slowly with improvements in capability. However, as one approaches the limits of technical feasibility -- represented by the "asymptote of impossibility" -- unit prices soar and provide little compensation in the form of improved performance. To move performance beyond the "state-of-the-art," it is necessary to invent new materials, develop new design concepts, increase testing, etc. This unceasing quest for progressively higher levels of performance is a primary cost driver in the defense sector.

[5]Cherniavsky, E.A., and Timperlacke, E.T., *Tacair Performance/Cost Analysis: Trends Over Time,* TASC, Technical Report TR-3222-3, September 1981.

Cost/Degree of Difficulty Curve



COIN Sample Output

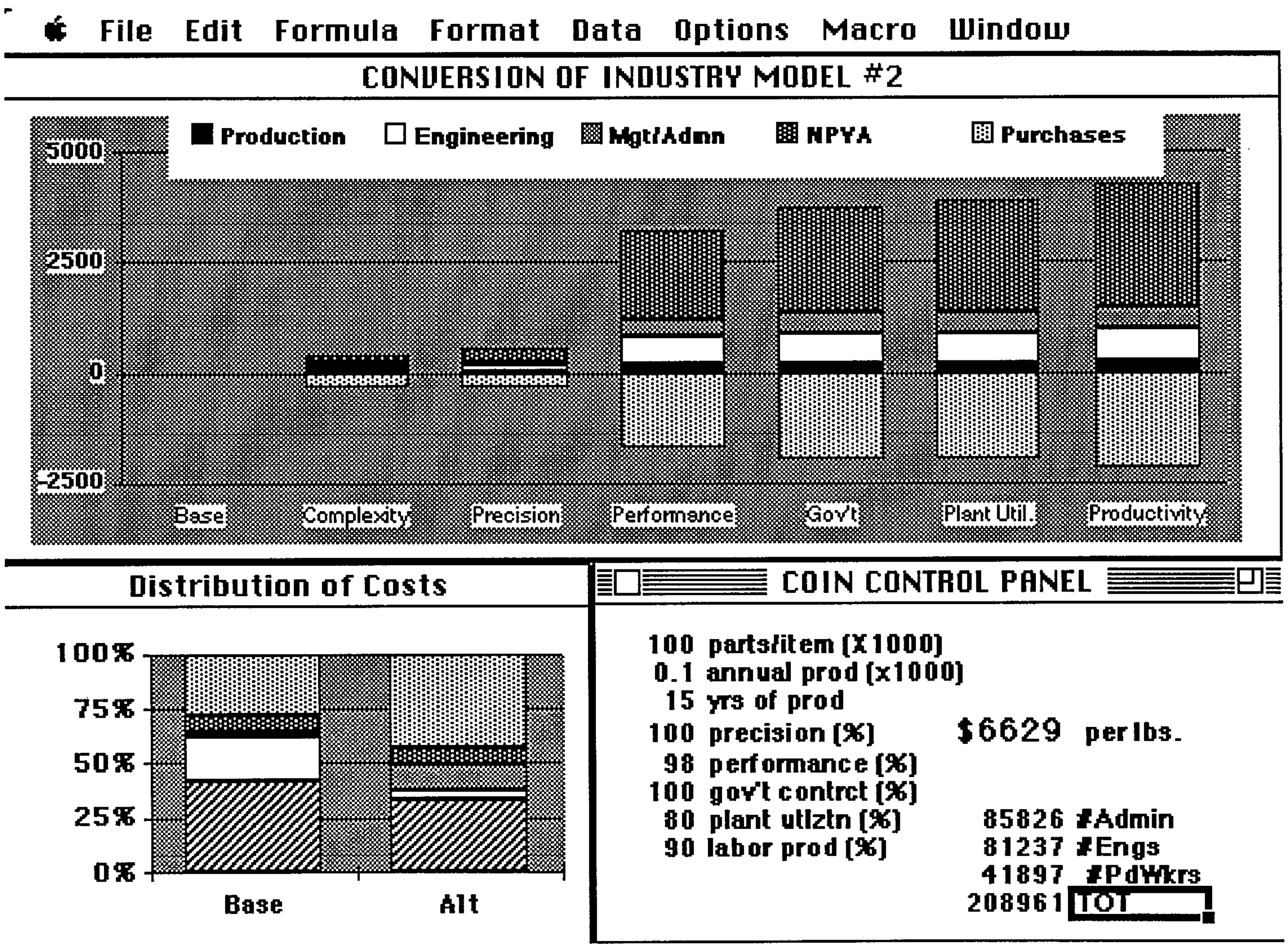
This sample COIN output screen reflects the full "conversion" of the 1000-employee refrigerator facility into the 200,000-employee aerospace sector.

The control panel is in the lower right quadrant of the slide. The production variables appear in the column on the left-hand portion of the control panel. When the user manipulates these variables (parts per item, annual production, years of production, level of precision, government contracting regulations, level of plant utilization, and labor productivity), the new conditions cause changes in both the output price (expressed in dollars per pound) as well as the size and composition of the workforce. The output price per pound and the number of executive/administrative, engineering/technical, and production worker personnel are shown on the right side of the control panel.

The figure in the lower left portion of the slide tracks changes in the distribution of costs utilizing our familiar industry cost framework. The "Base" column represents the cost distribution of the refrigerator facility, and reflects Census of Manufactures industry statistics. The "Alt" column summarizes the impact of the variables on the cost distribution of the "converted" facility or industry.

Finally, the top half of the output screen tracks the impact of specific variables on it prices (expressed in dollars per pound) as well as the distribution of costs. The algorithms used to project these impacts are discussed in greater detail in the following slides.

COIN Sample Output



COIN Demonstration -- Pass #1

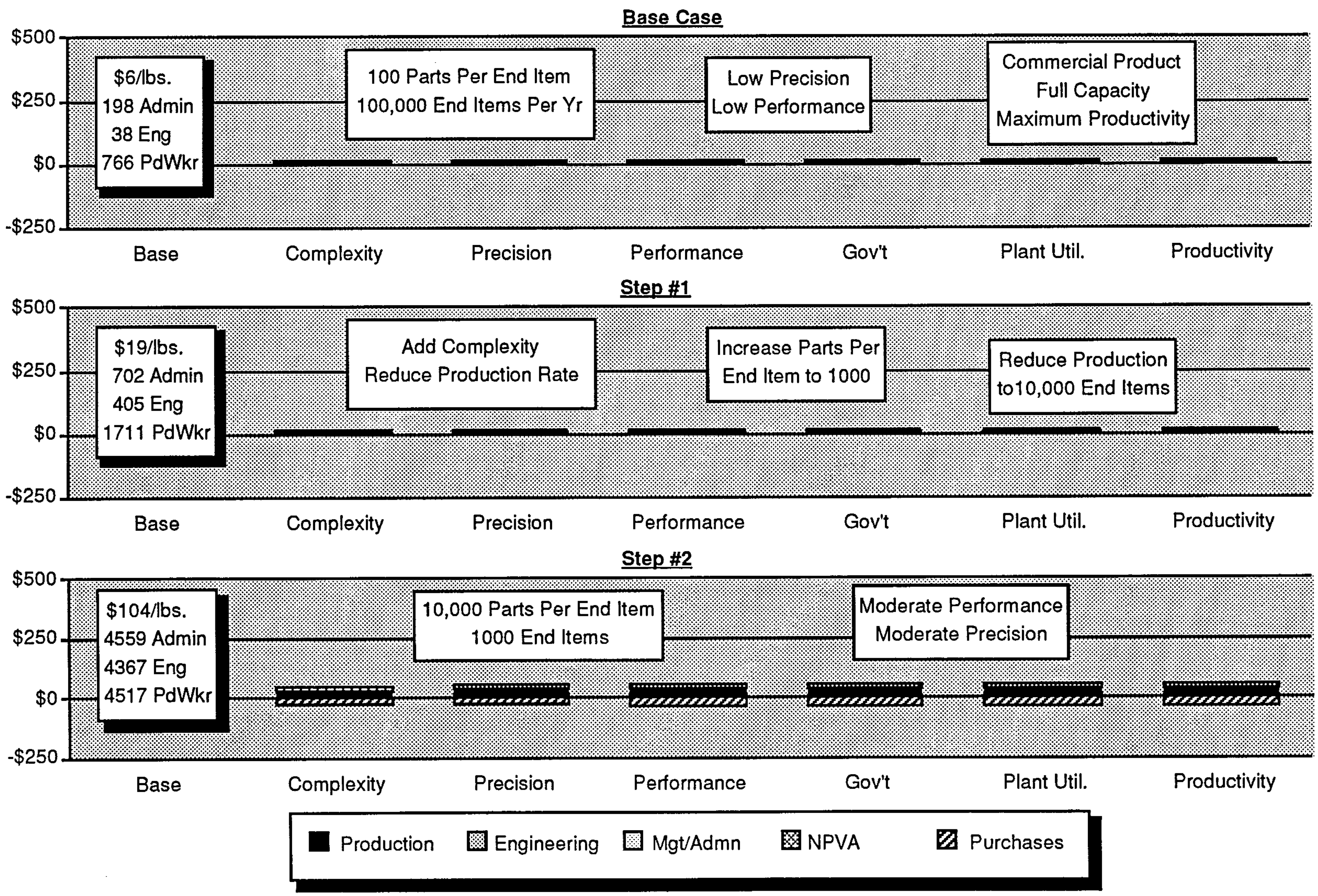
In the following demonstration, the appliance manufacturing facility is transformed into a high technology aerospace sector through a step-by-step process of "conversion." Each step has an individual impact on workforce requirements and output prices, which are tracked by an accompanying slide. Cumulative information on price per pound and workforce composition is provided with each step on the left-hand side of the slide.

Base Case: The base case is a refrigerator manufacturing facility with 1002 employees, of which over 75 percent are production workers and only about 4 percent are engineers and technical personnel. The facility produces 100,000 refrigerators a year, and each refrigerator contains 100 parts. Refrigerators weigh about 70-100 pounds, and cost about $6 per pound. We drew upon the Census of Manufactures and BLS sources to determine the workforce composition and production cost distribution of this hypothetical facility; the production rates, parts per end item figure, and price per pound are based on informal survey information.

Step #1: In this first step, we added complexity to the final product by increasing the number of parts per end item to 1,000. Since the total number of parts produced by our hypothetical facility/sector remains constant at 10 million parts per year (in order to maintain a fixed baseline), annual production falls to 10,000. As the number of parts increases by a factor of ten, we project that the engineering workforce (which must design the parts) must also grow tenfold. Because there are more parts per end item but fewer end items, repetitive tasks requiring few production workers using automated equipment are replaced by non-repetitive, precision operations requiring a larger number of workers, particularly skilled machinists and precision assemblers. These increases in the engineering and production staffs compel corresponding growth in the executive/administrative support at the rate of .76 per additional engineer and .22 per additional production worker (see "Workforce Composition Relationship," pg.). As a result, the total workforce approaches 2,800 employees, with engineers and technicians now accounting for almost 15 percent of the workforce. Finally, the reduction in production volumes causes a shift to metalcutting over metalforming, resulting in the consumption of more raw material and increasing total material costs. The cumulative impact of these factors results in the near tripling of output costs to $19 per pound.

Step #2: In this step, we add still greater levels of complexity to the final product by raising parts per end item to 10,000, thereby reducing annual production falls to 1000 end items annually. Following the pattern of Step #1, requirements for engineers, precision-oriented production workers, administrators escalate sharply, and material costs continue to grow. We have also increased both performance and precision to moderate levels (i.e., 40 percent of technical feasibility); however, the employment and unit cost impacts of these changes are relatively small because they occur on the relatively flat portion of the cost/performance curve. (A more detailed discussion of precision and performance effects is provided in Step #3.) The cumulative impact of the increases in complexity, precision, and performance result in a fivefold increase in unit costs to over $100 per pound. The workforce now totals over 13,000, roughly evenly divided between executives/administrators, engineers/technicians, and production workers.

COIN Demonstration -- Pass #1



COIN Demonstration -- Pass #2

Step #3: In this step, we increase parts per end item to 50,000, and reduce annual production to 200 units. This further increase in complexity and reduction in production volume have predictable effects: the engineering staff swells because of the necessity for designing and developing additional parts; the number of production workers also grows -- but at a slower rate -- and machine operators are increasingly replaced by high skill, high wage precision craft, trade, and assembly workers.

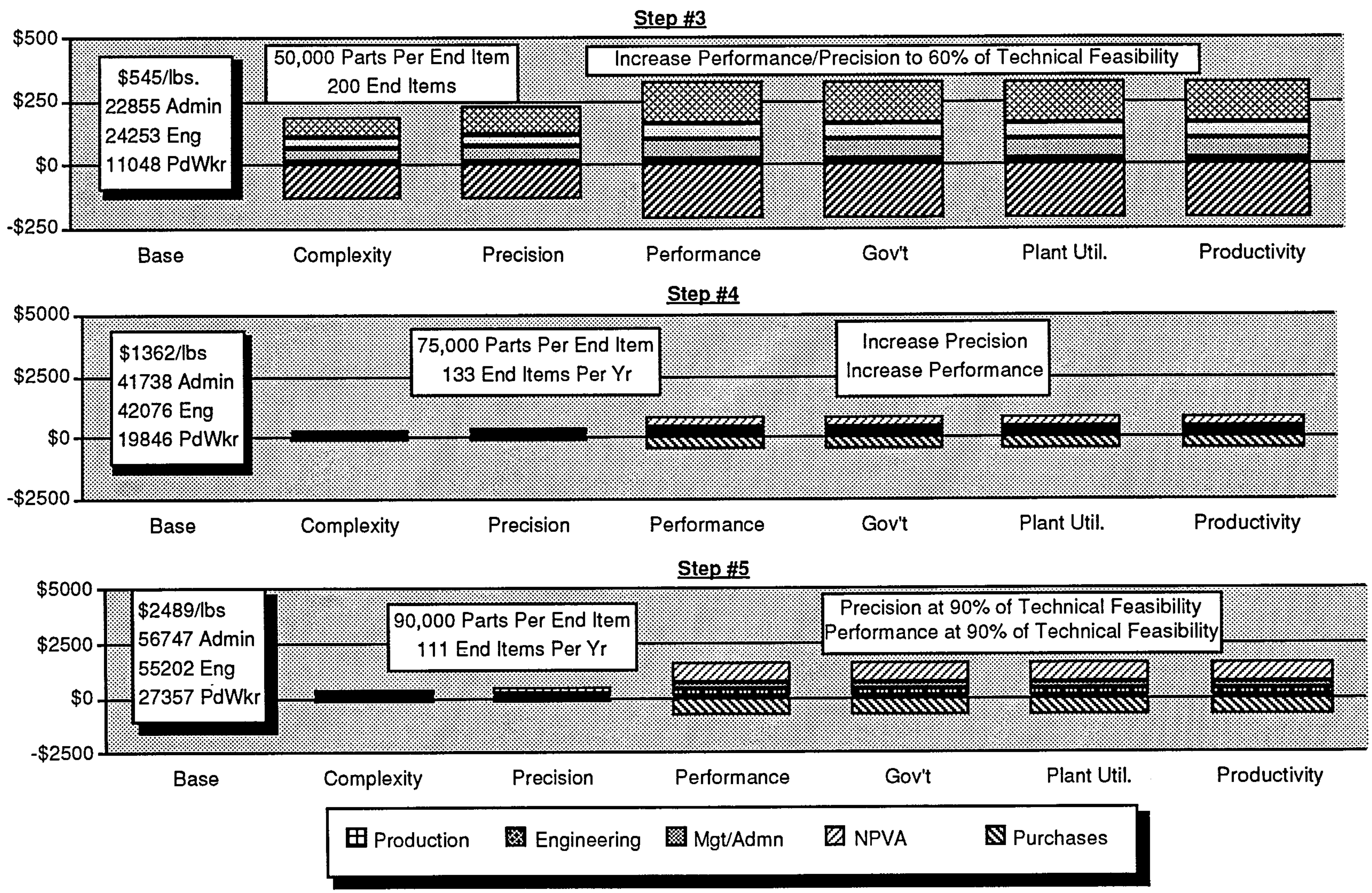
We also increase precision and performance to 60 percent of current technical limits. Here, it is important to distinguish between performance and quality. Improving performance (particularly in the transportation and defense sector) frequently involves reducing product weight. For example, lighter automobiles are generally more responsive than heavier vehicles, assuming comparable engine power. This shift requires the use of lighter, more expensive material such as specialized alloys and composites -- such materials require more time-consuming machining and are more difficult to assemble. In contrast, improvements in precision are generally realized through the use of heavier, more durable parts and the achievement of tighter parts tolerances resulting from more extensive machining. Greater precision therefore translates into substantial increases in materials costs; growth in the production workforce (since workers must take longer to produce each part); additional engineers (since it takes longer to design a high precision part); a swelling of the administrative staff (to support the new production workers and engineers); and more capital expenditures for precision metalworking equipment. Because of the inherent tension between precision and performance, efforts to improve both simultaneously result in substantial unit cost increases, particularly as they approach the prevailing technical limits.

These increases in complexity, precision, and performance and the reduction in production volume result in another fivefold increase in unit costs to $545 per pound. The workforce experiences comparable growth -- to about 56,000 -- with engineers and related personnel accounting for over 40 percent of total employees.

Step #4: Here, we establish performance and precision at the 80 percent level on the cost/performance curve, and increase the unit part count to 75,000. Following the patterns discussed, unit cost increase to $1362 per pound, and total employment exceeds 100,000. (Note that the slide scale has been changed to accommodate the higher output costs.)

Step #5: In this step, we increase the part count to 90,000, reduce annual production to 111, and raise the precision and performance level to 90 percent of the prevailing technical limits. Unit costs increase to nearly $2500 per pound, and total employment approaches 140,000.

COIN Demonstration -- Pass #2



COIN Demonstration -- Pass #3

Step #6: In this step, we increase the part count to 100,000, reduce the production rate to 100 end items per year, and set precision and performance levels near the limits of technical feasibility (i.e. 98 percent). (We regard the complexity, precision, and performance levels to be roughly comparable to an advanced military aircraft such as the B-2.) As a result, unit costs increase to over $4500 per pound, and total employment exceed 170,000.

Step #7: Next, we move our imaginary aircraft into the DoD acquisition environment. Our analysis of the defense industry workforce indicates that the DoD environment has a visible impact on production support workers such as inspectors and security personnel. While we see no significant direct impact on administrative employment, the DoD environment appears to increase engineering staffs as a result of documentation and other requirements (which, in turn, generates additional requirements for administrative support workers). The cumulative cost impact of our "guestimates" in these areas totals about 15 percent. We have also reduced plant utilization by 30 percent in light of the high level of excess capacity prevailing in the defense sector. We have also (somewhat arbitrarily) reduced labor productivity by 10 percent to reflect the relative lack of incentives in the defense sector to minimize costs and the general impact on productivity of intensive government oversight. Together, these market-oriented factors raise unit costs to just under $6000 per pound, an increase of approximately 30 percent. Workforce employment totals 210,000: administrators -- 41 percent; engineers/technicians -- 39 percent; production workers -- 20 percent.

The resulting "converted" industry is roughly consistent with our expectations regarding the unit costs, workforce size and composition, and cost distribution of an imaginary aircraft sector that produces 100 B-2 aircraft in a single year. For example, in the 1990-92 period, eight B-2 bombers were procured at a total estimated cost of $7.3 billion, or about $800 million per aircraft.[6] Since the empty weight of a B-2 is approximately 100,000 pounds, we derive a unit cost estimate of about $600 million for our imaginary annual production volume of 100 aircraft -- probably an appropriate estimate in light of the economies of scale likely to be achieved through the higher production volume. The size of our imaginary B-2 workforce is plausible given the scale of the Northrop B-2 facility, which produces only 2-3 aircraft per year (in contrast to our imaginary volume of 100). Our workforce composition estimates are based on our understanding regarding the administrative manpower support requirements of engineers and production workers, as well as the common-sense assumption that (all other factors being equal) engineering requirements are proportional to the number of parts per end item. The cost distribution pattern (i.e., production worker wages account for small portion of total costs; payroll costs represent only about 20 percent of total costs; high level of NPVA costs) is representative of an industry sector with an extreme high technology orientation.

In our view, COIN provides a coherent explanation of how various product- and market-oriented factors contribute to high unit costs in the defense sector. We believe that, through case study analysis, it would be possible to validate with a relative confidence many of the relationships utilized in this prototype model. With further work, COIN could be developed into a very useful conceptual and educational tool, and may even be utilized in a variety of cost estimating applications.

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[6] Aerospace Industries Association, *Aerospace Facts and Figures -- 1991/1992.*

COIN Demonstration -- Pass #3